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Digital Financial Inclusion and Institutional Quality as Drivers of Green Economic Growth: Pathways to Sustainable Development

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ABSTRACT

The transition to a green economy has become a critical policy objective for sustainable development, with digital financial inclusion (DFI) serving as a key enabler of this shift. This study examines the relationship between financial inclusion broken down into traditional and digital components and green economic growth (GEG) in South-Eastern Europe (SEE) countries from 2011 to 2021, while also assessing the role of institutional quality. Using a fixed effects regression model, we analyze constructed indices for financial inclusion and institutional quality, which are constructed Principal Component Analysis (PCA). The results reveal that both digital and traditional financial inclusion (TFI) positively influence GEG, underscoring their role in advancing sustainability. However, institutional quality has a positive but insignificant impact on GEG, suggesting that governance weaknesses may hinder progress. This finding highlights the need for institutional reforms, particularly in governance and the rule of law, especially for non-EU countries, to better support green economic initiatives. Based on these insights, the study recommends that SEE, non-EU countries strengthen their regulatory frameworks to enhance transparency, security, and efficiency in digital financial services. Key measures include improving institutional quality (e.g., data security and consumer protection), expanding digital infrastructure, and promoting financial literacy. Such efforts are essential to fostering trust in digital finance and creating an enabling environment for sustainable, inclusive growth.

1. INTRODUCTION

The revolution of digital financial inclusion (DFI), powered by various forms of fintech, is crucial for a country's economic development and competitiveness. It provides economic entities—the engines of growth and job creation—with easy, fast, and cost-effective access to financial services, contributing to improved community quality of life. Simultaneously, the green economy has become a central policy focus in the pursuit of sustainable development.

The impact of DFI on a country's economy is multifaceted, influencing environmental sustainability, economic growth, and social well-being. By expanding financial access, encouraging sustainable investments, and enhancing resource efficiency, it contributes to a greener economy. The continuous advancement of financial technologies further strengthens their role in promoting environmental sustainability and accelerating the shift toward a low-carbon, resource-efficient economy.

The COVID-19 pandemic has transformed digital financial services, making DFI crucial to ensure universal access to these services and foster sustainable economic growth. Efforts to advance DFI should align with and contribute to achieving the 2030 Sustainable Development Goals (SDGs) [1].

DFI has been widely studied in relation to economic growth, with many analyses concluding that it enhances economic development and can contribute to GDP growth [2-6].

The concept of inclusive green growth focuses on achieving SDGs by fostering equality in economic growth and promoting green economic benefits. It seeks to address social and environmental challenges arising from traditional, unsustainable economic practices. Within the framework of inclusive green growth, the emphasis is on advancing an "inclusive" and "green" strategy for sustainable economic development. This approach has become a crucial initiative for developing countries to meet their dual-carbon targets while maintaining social harmony and stability.

Researchers argue that financial inclusion through green finance is closely linked to climate action, as it enables individuals and businesses to invest in environmentally friendly technologies and practices. It enables businesses to invest in green industries such as renewable energy projects, solar panels, wind turbines, and energy-efficient equipment. This shift in investment behavior among entrepreneurs and businesses fosters climate resilience by expanding access to renewable energy for marginalized communities [7], which are often more vulnerable to the impacts of climate change. Consequently, financial inclusion is recognized as a critical driver of green economic growth (GEG) and the achievement of SDG 13 on climate action.

Several countries in South-Eastern Europe (SEE), particularly those in the Western Balkans, still remain transition and developing economies with relatively low economic growth. Although these economies have achieved moderate industrial development, they also suffer from high levels of environmental pollution with high carbon dioxide emissions. Environmental pollution mainly results from the lack of investment in gasification. Households, businesses and public institutions still use environmentally unfriendly energy sources. Low-income levels, politicization of institutions, corruption, lack of rule of law, low investment in renewable energy, low culture for environmental protection do not support sustainable economic development.

The study aims to assess the impact of DFI and institutional quality on GEG by analyzing data from countries in the SEE region from 2011 to 2021. Specifically, we focused on various digital financial instruments and examined their effects on green economic efficiency. Based on the purpose of the paper, we have derived the following hypotheses:

H1: *DFI can contribute to GEG by improving access to sustainable finance and promoting the efficient allocation of resources in environmentally sensitive sectors.*

H2: *Institutional quality supports and enables sustainable economic growth.*

H3: *The interplay between DFI and institutional quality has a synergistic effect on GEG.*

2. LITERATURE REVIEW

National aspirations for rapid economic development have led to severe environmental consequences, including heightened pollution, rising carbon emissions, widespread land degradation, accelerated climate change, biodiversity loss, and extensive deforestation. In this context, global initiatives like the SDGs aim to drive improvements in economic and social performance, considering economic and social prosperity linked to environmental preservation. Implementing aims by 2030 will depend on the cooperation of governments, businesses and civil society. Green growth is an important and critical component for achieving sustainable development and mostly amounts to good growth policies [8]. However, the transition to a circular and regenerative green economy remains challenging, primarily due to insufficient economic incentives. In recent decades, green finance has emerged as a promising solution to help overcome this obstacle [9].

Recent technological developments have led to the rapid expansion of DFI, driving transformative changes in the finance industry. The key attributes of this innovation are low cost, broad and rapid access to finance, and efficient distribution of information across time and space, which have significantly impacted both economic growth and social development.

Financial inclusion plays a crucial role in enhancing national performance, while the green economy has become a key driver of ecological sustainability. The growth of financial inclusion can support greater green economic efficiency, largely by imposing stricter credit restrictions on companies that emit carbon [10].

Recent studies have highlighted the significant impact and effectiveness of DFI in promoting and expanding the green economy. Specifically, the findings of Peng and Zeng [11] indicate that inclusive digital finance plays a crucial role in fostering regional green growth by driving green technology innovation, supporting entrepreneurship, and enhancing industrial structures through environmentally friendly technological advancements. Digital finance significantly boosts inclusive green growth by fostering technological innovation [12]. Similarly, Song et al. [13], researching the effects of DFI on the green economy, conclude that DFI promotes the green economy and has a significant positive spillover effect. However, they also find that while regional competition benefits the green economy's development, the interaction between DFI and regional competition has an adverse effect. In this context, some authors, such as Xi and Wang [14], have examined the impact of DFI on the quality of economic growth. They define the quality of economic growth based on factors such as technological innovation, coordinated development, environmental protection, openness to global markets, and improvements in quality of life. Their research results show that DFI positively impacts the quality of economic growth, stimulates entrepreneurship, and promotes economic improvement. Sustainable development of DFI can significantly increase economic quality.

The role and impact of digital inclusion on traditional and GEG have attracted considerable interest from researchers. Many are also exploring the effects of DFI on various economic sectors, including enterprise digital transformation [15], agriculture [16], tourism [17], energy efficiency [18-20]. The development of inclusive digital finance significantly enhances agricultural productivity gains, and this positive effect tends to increase as traditional financial channels also develop [16]. In this context, Luo et al. [17] investigate the impact of DFI on tourism development, concluding that it enhances tourism by increasing individual participation in financial markets, fostering entrepreneurship in the tourism industry, and boosting tourism-related spending. The development of inclusive digital finance significantly amplifies agricultural productivity gains, and this positive effect stands to be further elevated as traditional financial avenues also evolve.

But according to Ozturk and Ullah [21], who examine the relationship between financial inclusion, environmental sustainability, and economic growth of the One Belt One Road Initiative economies the DFI increases economic growth, but it negatively affects environmental quality by contributing to increased CO_2 emissions.

Institutions influence the incentives that guide individual choices and behavior, thus playing a crucial role in shaping the development path of an economic system, its growth potential, and the degree of inequality [22].

Theories and research on the mechanisms of economic growth and development, since Adam Smith, in addition to the fundamental factors of economic growth (capital, human resources, natural resources, innovation, education, etc.), have also emphasized the role of institutions in economic growth and development. According to the views of North and Thomas [23], the main explanation of differences in economic growth lies in differences in the quality of institutions. North [24] defined institutions as “the rules of the game in a society,” or the human-created constraints that shape human, political, social and economic interaction.

Economic institutions establish the incentive structures and constraints that govern economic behavior, thereby influencing resultant economic performance [25]. In recent years, extensive research has explored the relationship between institutional quality and economic outcomes [26].

According to Chinoda and Kapingura [27], institutional quality and governance have a substantial positive impact on the relationship between DFI and economic growth in Sub-Saharan Africa (SSA). Additionally, the authors conclude that trade and population growth contribute positively to economic growth, whereas inflation has a detrimental effect on the region's economic growth. Inclusive green growth is essential for achieving sustainable economic development.

Regarding the contributions of institutional quality to green economies, the results vary depending on the level of corruption, political stability, rule of law, regulatory quality and the governance effectiveness of a country's institutions. In this regard, the findings of the research study by Degbedji et al. [28] reveal that the effect of institutional quality on GEG varies significantly across countries. In particular, stronger institutions contribute positively to GEG in countries such as Côte d'Ivoire, Mali, Niger, Senegal and Togo. Conversely, institutional quality appears to hinder GEG in countries such as Benin and Burkina Faso. These results suggest that the relationship between institutional frameworks and sustainable development is context-dependent, highlighting the need for tailored policy approaches.

Our study contributes significantly to the existing literature as the first empirically grounded research examining the impact of DFI on GEG in the SEE region, with a particular focus on the mediating role of institutional quality.

Most countries in the SEE region, particularly the less developed ones, prioritize economic development over environmental sustainability. This results in weaker climate change mitigation efforts and lower environmental protection standards compared to developed nations. Such trends are evident in persistently high air pollution levels (especially during winter) and inadequate waste management and recycling systems. Furthermore, limited subsidies and policy incentives for clean energy and environmental initiatives reinforce a growth-oriented approach that frequently neglects ecological concerns. By analyzing the interplay between DFI, institutional quality, and GEG, this study provides critical insights into sustainable development challenges in the SEE region.

3. METHODS

This study measures the nexus between DFI and IQI as a mediating variable on GEG for selected SEE countries (Albania, Austria, Bosna and Hercegovina, Bulgaria, Croatia, Czechia, Greece, Montenegro, North Macedonia, Hungary, Romania, Italy, Serbia, Slovenia, Slovak Republic and Turkiye for years 2011, 2014, 2017 and 2021. As Global Findex survey data is only available for these years. From this sample, we have excluded some SEE countries due to lack of data.

The purpose of this paper is to evaluate the role and impact of DFI and institutional quality on GEG. Building on the work of Khera et al. [29] and Miftari et al. [30], we develop a DFI index and Traditional Financial Index (TFI) by applying the Principal Component Analysis (PCA) method, enabling the integration of multiple indicators into a unified composite measure. This statistical technique is used to reduce the dimensionality of the data, identifying patterns and simplifying the dataset by transforming correlated variables into a set of linearly uncorrelated components (principal components). A one-stage PCA is used to construct this index.

IQI constructed through PCA method from four World Development Indicators (political stability, rule of law, regulatory quality, and government effectiveness), was introduced as a mediating variable alongside the primary independent variables.

IQI serves as a proxy for governance effectiveness, which can strengthen the role of DFI in fostering GEG by improving policy implementation, regulatory oversight, and resource allocation efficiency.

Following growth theory, we incorporate control variables like final consumption expenditure (FCE). FCEs have a significant impact on economic activities [31, 32]. Additionally, it can be linked to GEG in various forms and ways.

We also include Foreign Direct Investment (FDI) and Trade (TR) as instrumental variables to account for additional factors that may influence both economic growth and GEG.

Table 1. Variables descriptions

Variables	Measurement	Data Source
TFI		Authors calculation (PCA)
Access	Number of ATMs per 100.000 adults Number of Branches per 100.000 adults % of adults with debit cards % of adults who receive wages through a financial institution account % of adults who use a financial institution account for utility	FII
DFI		Authors calculation (PCA)
Access	Mobile subscription per 100 people % of the population who have access to the internet Number of registered mobile money agents per 100.000 adults	ESG
Usage	% of adults who have a mobile account % of adults who use the internet to pay % of adults who use mobile phones to make untilitx payments	
IQI	Political stability and absence of violence, rule of law, regulatory quality, and government effectiveness.	Authors calculation (PCA) WDI
Dependent Variable		
GEG	GEG =GDP+EE-NRD-CO_2 GDP=gross domestic product growth (annual%) EE=education expenditure-merit good (% of GDP) NRD= net resources depletion CO_2=carbon emissions	Authors calculation
Instrumental Variables		
FCE	Final consumption expenditure (% of GDP)	WDI
FDI	Foreign Direct Investment, net inflows (% of GDP)	WDI
TR	Trade (% of GDP)	WDI

Data was gathered from various sources, with detailed information on variable definitions, measurements, and sources available in Table 1. The main aim is to assess the impact of two components of financial inclusion (FI) and IQI on GEG. Additionally, the research examines the relationships

among final consumption expendituare (FCE), trade openness (T), FDI, and GEG. TFI and digital financial index (DFI) were developed using PCA, with results presented in Appendix Table A1-A3.

Following previous studies [33, 34], we calculated GEG using the formula GEG=GDP+EE−NRD−CO_2.

GDP indicates the monetary value of goods and services, (annual%), EE is the monetary value of education spending (% of GDP), NFD is natural resources depletion (% of GNI), and CO_2 is the monetary value of carbon dioxide emissions. GEG is calculated by adjusting traditional GDP to account for both positive contributions and undesirable outcomes. On the positive side, we incorporate education expenditure as a key driver of sustainable development, recognizing its role in fostering innovation, green skills, and long-term productivity. On the negative side, we deduct net resource depletion and carbon emissions to reflect environmental degradation costs. This adjusted metric provides a more comprehensive view of economic progress by balancing growth with ecological and social sustainability.

The literature reveals methodological diversity in assessing financial inclusion's effect on GEG, with different studies applying fixed effects specifications, pooled OLS regressions, dynamic GMM frameworks, etc.

To identify the most appropriate regression model for our dataset, whether it be pooled OLS, fixed effects, or random effects, the results of Hausman test revealed that robust fixed effects regression model is preferred due to the correlation between the individual effects and the regressors. The results of modified Wald test for groupwise heteroskedasticity in fixed effect regression model show existence of heteroscedasticity, and finally we use the robust fixed effect model. Furthermore, the fixed-effects approach enables more robust estimation of DFI's impact on green growth by controlling for unobserved countries specific heterogeneity. The empirical model is specified as follows:

$$Y_{it} = \alpha_{it} + \beta X_{it} + \delta_t + \mu_{it} + \varepsilon_{it} \quad (1)$$

The model specification is as follows:

$$GEG_{it} = \beta_0 + \beta_1 TFI_{it} + \beta_2 DFI_{it} + \beta_3 IQI_{it} + \beta_4 FCE_{it} + \beta_5 FDI_{it} + \beta_6 TR_{it} + \delta_t + \mu_{it} + \varepsilon_{it} \quad (2)$$

$$GDP_{it} = \beta_0 + \beta_1 TFI_{it} + \beta_2 DFI_{it} + \beta_3 IQI_{it} + \beta_4 FCE_{it} + \beta_5 FDI_{it} + \beta_6 TR_{it} + \delta_t + \mu_{it} + \varepsilon_{it} \quad (3)$$

To test the moderating role of institutional quality on the impact of DFI on GEG we developed this regression equation:

$$GDG_{it} = \beta_0 + \beta_1 TFI_{it} + \beta_2 DFI_{it} + \beta_3 IQI_{it} + \beta_4 (DFI_{it} \times IQI_{it}) + \beta_5 FCE_{it} + \beta_6 FDI_{it} + \beta_7 TR_{it} + \delta_t + \mu_{it} + \varepsilon_{it} \quad (4)$$

where,

GEG_{it} = Green economic growth (dependent variable)

GDP_{it} = Gross Domestic Product

TFI_{it} = Traditional financial inclusion index (explanatory variable)

DFI_{it} = Digital financial inclusion index (explanatory variable)

IQI_{it} = Institutional quality index (mediating variable)

($DFI_{it} \times IQI_{it}$) = Interaction term

FCE_{it} = Final consumption expenditure (control variable)

FDI_{it} = Foreign Direct Investment (control variable)

TR_{it} = Trade (control variable)

i = Cross-sectional unit (countries)

T = Time period (year)

μ_i = Country-specific fixed effects (time-invariant heterogeneity)

δ_t = Time-specific effects (coefficient for year fixed effects)

ε_i = Error term

4. DATA ANALYSIS

The descriptive statistics shown in Table 2 illustrate the varying trends and distributions of the variables. The variables IQI (2.054659), FCE (9.731441), FDI (3.879896), and trade (37.13895) exhibit the highest standard deviations, signifying considerable variability among them.

Table 2. Summary statistics

Variable	Min	Max	Std.Dev.	Mean	Obs
GEG	13.38959	13.51657	4.384611	1.485743	64
TFI	3.500157	4.05823	1.6855	1.29e-08	64
DFI	5.918418	5.060571	1.710085	9.18e-10	64
IQI	-3.790669	4.779093	2.054659	-5.12e-09	64
FCE	67.29223	106.3196	9.731441	81.13305	64
FDI	8.644798	18.38888	3.879896	4.096216	64
TRADE	53.30418	186.6447	37.13895	107.7931	64

Table 3 displays the correlations among the variables, revealing primarily weak positive and negative relationships. GEG demonstrates a low positive correlation with TFI (0.0384), DFI (0.0259), and FDI (0.1548). Additionally, there is a low negative correlation between GEG and IQI (-0.1793), FCE (-0.2595), and Trade (-0.0275).

Table 3. Correlation analysis

	GEG	TFI	DFI	IQI	FCE	FDI	TR
GEG	10000						
TFI	0.0384	1.0000					
DFI	0.0259	0.7515	1.0000				
IQI	-0.1793	0.6728	0.5082	10000			
FCE	-0.2595	-0.4743	-0.3585	-0.6032	1.0000		
FDI	0.1548	-0.1327	-0.0532	-0.1280	0.2748	1.0000	
TR	-0.0275	0.3545	0.3269	0.4621	-0.4210	0.1016	1.0000

Multicollinearity diagnostics were performed using the variance inflation factor (Table 4). The results revealed that the level of multicollinearity is low VIF=2.04 (VIF<5). Thus, the regression coefficients can be reliably interpreted, as multicollinearity does not compromise their stability.

The results of the regression analysis presented in Table 5 indicate that Traditional Financial Inclusion (TFI) has a positive association with GEG (0.335), but this association is insignificant (p=0.351). Similarly, the DFI index, with a coefficient of 0.563, also shows a positive effect, yet the p-value of 0.351 indicates this is not statistically significant. This suggests that while DFI may have a potential positive influence on GEG, it does not have a significant impact.

Table 4. Multicollinearity test

Variable	VIF	1VIF
TFI	3.16	0.316801
IQI	2.37	0.421403
DFI	2.33	0.429476
FCE	1.81	0.552260
TR	1.43	0.701500
FDI	1.16	0.862331
Mean VIF	2.04	

Table 5. Dependent variable GEG

	TFI	DFI	IQI	FCE	FDI	TR
Statistics	.3352766	.5630774	.2850019	-.3951206	.1493141	.1459516
P value	(0.510)	(0.351)	(0.793)	(0.005)*	(0.228)	(0.070)**
R-sq			0.4705			
rho			0.9083			

Note: * significant at the level 5%, and ** significant level at 10%.

The IQI index exhibits a positive relationship of 0.285, but the high p-value (p=0.793) demonstrates a lack of statistical significance, implying that IQI does not significantly predict GEG. In contrast, FCE is noteworthy; it has a statistically significant impact on GEG (p=0.005) and indicates that a 1% increase in FCE is associated with a decrease of 0.395% in GEG. This suggests that final consumption may pose a significant obstacle to achieving GEG.

FDI shows a positive relationship (0.149), but with a p-value of 0.228, this relationship is not statistically significant. On the other hand, Trade presents a positive relationship with GEG (0.145) and has a significant value at the 10% level (p=0.070), indicating that a 1% increase in trade is associated with a 0.145% increase in GEG.

The interaction analysis (Table 6) reveals a positive but statistically insignificant coefficient for the interaction term DFI - IQI. While this suggests a possible amplifying effect of institutional quality on the relationship of DFI with green economic development, the lack of statistical significance (p>0.05) precludes definitive conclusions regarding this conditional relationship.

Table 6. Interaction term regressions

	TFI	DFI	IQI	DFIIQI***	FCE	FDI	TR
Statistics	.293972	.5408093	.2465419	.0805584	-.3727774	.1483791	.147328
p Value	(0.542)	(0.400)	(0.823)	(0.764)	(0.021)*	(0.228)	(0.072)**
R-sq					0.4728		
rho					0.9034		

Note: * significant at the level 5%, and ** significant level at 10%
*** Interaction term

5. DISCUSSION

This research aims to explore the influence of financial inclusion and institutional quality on GEG, alongside control variables such as FCE, FDI, and trade. The study employed regression analysis using a fixed effects model. The findings indicate that financial inclusion, categorized into traditional and DFI, has a positive but statistically insignificant effect on GEG. Our results align with the work of [11, 21, 35]. These findings reveal that DFI is positively associated with GEG as well. But in contrast with those of Abass [34], whose research indicates a significant negative impact of financial inclusion on GEG. The weak link between DFI and GEG in SEE countries stems from multiple structural and institutional factors. These include: a disproportionate focus of DFI on payment services rather than green lending products; the continued market dominance of traditional banks that favor conventional over sustainable financing; limited opportunities for green investment across the region, etc. Furthermore, the results of this study also indicate an insignificant positive relationship between institutional quality and GEG. These findings are consistent with those of Tiwari and Bharadwaj [36], who found that countries with more stable institutions tend to experience higher economic growth but contradict the conclusions of Meniago [26] and Degbedji [28]. The limited impact of institutional quality on GEG can be attributed to significant heterogeneity in governance frameworks across the region, particularly between EU and non-EU member states in SEE. Non-EU countries exhibit notably higher levels of corruption, weaker rule of law, and lower institutional investments in innovation and development compared to their EU, aligned counterparts factors that critically constrain their capacity to foster sustainable growth.

At first glance, a negative coefficient for FCE appears to contradict the principles of economic growth, including GEG. However, this observation can be understood in the context of declining economic growth, particularly during the period from 2011 to 2020, when both households and businesses reduced their consumption, leading to decreased economic activity. If final consumption does not prioritize sustainable goods and services, it can have detrimental effects on the environment and hinder progress toward green growth objectives [37].

Additionally, a negative FCE index may indicate a shift in consumer behavior towards increased savings. Although this shift may hinder short-term economic growth, it could encourage long-term sustainability by fostering green investments.

In summary, while a negative FCE index might seem harmful to immediate economic growth, it could also signal a transition towards more sustainable consumption patterns and investments in green technologies. This shift represents a long-term commitment to an economy that prioritizes environmental sustainability over short-term growth.

While control variables such as FDI and trade revealed a significant positive relationship with GEG and economic growth.

6. CONCLUSION

The study investigates the relationship between financial inclusion specifically both traditional and DFI, and the impact of institutional quality on GEG in SEE countries during the period from 2011 to 2021. It also considers macroeconomic variables such as FCE, FDI, and trade.

The results of the regression analysis confirm a positive relationship between DFI and TFI, though the impact is found to be relatively low. However, this suggests a pressing need for further expansion of digital inclusion initiatives by economic entities.

An additional contribution of the study is its examination of how institutional quality facilitates the relationship between digital inclusion and GEG. The regression analysis indicates a statistically insignificant negative relationship between institutional quality and GEG, implying that weaker institutional frameworks may hinder sustainable development. This finding suggests that declining institutional quality is linked to reduced GEG, highlighting the crucial role of strong governance in advancing environmentally sustainable economic policies.

This study specifically recommends that SEE countries prioritize strengthening governance and regulatory frameworks to increase transparency, security, and efficiency in digital financial services. Improving institutional quality requires comprehensive reforms that focus on: anti-corruption measures, improvements in the regulatory framework, public sector efficiency, and strengthening the judicial system. European integration processes provide mechanisms for institutional convergence with global sustainability standards. In addition, improving institutional quality by ensuring strong oversight in critical areas such as data protection, consumer rights, and fraud prevention to foster trust in digital finance. Expanding Digital Infrastructure by investing in accessible and reliable digital networks to expand financial inclusion. Promoting Financial Literacy by Implementing targeted educational programs to empower users to effectively navigate digital financial tools.

These steps are vital to creating an enabling environment where DFI can drive sustainable economic growth.

6.1 Limitations of the study and future research

A key limitation of this study stems from data constraints on financial inclusion variables, as Global Findex data are only available for select years (2011, 2014, 2017, and 2021). This restricted temporal coverage may limit the analysis's scope and generalizability. Furthermore, while data on institutional quality are obtained from relevant databases, they may not fully capture the complexity and diversity of governance in the SEE region.

The dimensionality of research focused on factors influencing GEG and sustainable development is quite broad, offering numerous opportunities for further exploration. Therefore, future studies could benefit from including a wider range of variables related to DFI, as well as green loans provided by financial intermediaries. This would facilitate a more complete understanding of the role that banking industry factors play in fostering GEG.

Furthermore, it is recommended that future research replicate this study across different regions, using comparative analyses between groups of countries based on their levels of development, in order to examine and explore regional variations.

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APPENDIX

Table A1. PCA for TFI

Component	Eigenvalue	Difference	Proportion	Cumulative	
C1	2.84091	1.76689	0.5682	0.5682	
C2	1.07402	.416469	0.2148	0.7830	
C3	.657548	.313674	0.1315	0.9145	
C4	.343875	.260224	0.0688	0.9833	
C5	.083651	.	0.0167	1.0000	
		Principal Components (Eigenvectors)			
Variable	C1	C2	C3	C4	C5
Tfi1	-0.1452	0.8516	0.4912	-0.0769	0.0807
Tfi2	0.5580	0.0224	0.1835	-0.3819	-0.7132

Tfi3	0.4890	-0.0953	0.4149	0.7570	0.0811
Tf4	0.3412	0.5140	-0.7427	0.2562	-0.0452
Tf5	0.5585	-0.0316	0.0348	-0.4578	0.6901

Note: Tfi1, Tfi2, Tfi3, Tfi4, and Tfi5 are: number of branches per 100.000 adults; % of adults with debit cards; % of adults who receive wages through a financial institution account; number of ATMs per 100.000 adults; and % of adults who use a financial institution account for utility, respectively.

Table A2. PCA for digital financial inclusion

Component	**Eigenvalue**	**Difference**	**Proportion**	**Cumulative**	
C1	2.92439	1.98334	0.5849	0.5849	
C2	.941054	.361813	0.1882	0.7731	
C3	.579241	.127194	0.1158	0.8889	
C4	.452047	.348781	0.0904	0.9793	
C5	.103266	.	0.0207	1.0000	
		Principal Components (Eigenvectors)			
Variable	**C1**	**C2**	**C3**	**C4**	**C5**
Dfi1	0.4454	-0.1955	0.5562	0.6725	0.0413
Dfi2	0.5263	-0.3015	-0.0887	-0.3185	-0.7231
Dfi3	0.5142	-0.3392	-0.1630	-0.3466	0.6884
Df4	0.3224	0.7361	0.4567	-0.3796	0.0389
Df5	0.3954	0.4625	-0.6690	0.4267	-0.0109

Note: Dfi1, Dfi2, Dfi3, Dfi4, Dfi5 are digital payment; % of adults who use the internet to pay; % of adults who use mobile phone to make utility payments; mobile subscription per 100 people; % of population who has access to internet; number of registered mobile money agents per 100.000 adults, respectively.

Table A3. PCA for institutional quality

Component	**Eigenvalue**	**Difference**	**Proportion**	**Cumulative**	
C1	4.22162	3.83504	0.8443	0.8443	
C2	.386584	.219428	0.0773	0.9216	
C3	.167156	.028001	0.0334	0.9551	
C4	.139155	.0536743	0.0278	0.9829	
C5	.0854812	-	0.0171	1.0000	
		Principal Components (Eigenvectors)			
Variable	**C1**	**C2**	**C3**	**C4**	**C5**
Iq1	0.4188	0.7666	0.1188	0.4498	-0.1430
Iq2	0.4490	-0.3033	-0.7578	0.3400	0.1290
Iq3	0.4493	-0.3919	0.6088	0.2371	0.4665
Iq4	0.4622	-0.2962	0.1595	-0.2190	-0.7907
Iq5	0.4556	0.2811	-0.1246	-0.7602	0.3464

Note: Iq1, Iq2, Iq3, Iq4, Iq5 are political stability; regulatory quality; government effectiveness; rule of law; voice and accountability, respectively.