“Entrepreneurial business intelligence and green innovation in international banks: The mediating role of sustainability practices”

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ENTREPRENEURIAL BUSINESS INTELLIGENCE AND GREEN INNOVATION IN INTERNATIONAL BANKS: THE MEDIATING ROLE OF SUSTAINABILITY PRACTICES

Abstract

The study aims to examine the relationship between entrepreneurial business intelligence and green innovation, as well as the mediating effect of sustainability practices. Data were collected in July and August 2025, focusing on managers and departmental heads at seven major international banks: HSBC, Citibank, Standard Chartered, Deutsche Bank, Barclays, Bank of America, and BNP Paribas. A total of 400 questionnaires were distributed online, of which 378 valid responses were retained for analysis, and participants were mainly from selected branches and regional offices in Europe and North America. PLS-SEM was conducted using SmartPLS 4. The findings showed that entrepreneurial business intelligence had a positive and statistically significant effect on green innovation ($\beta = 0.228$, $p < 0.001$). Additionally, entrepreneurial business intelligence exerted a significant positive effect on sustainability practices ($\beta = 0.365$, $p < 0.001$). Sustainability practices also exerted a positive and statistically significant effect on green innovation ($\beta = 0.405$, $p < 0.001$). Sustainability practices were found to mediate the relationship between entrepreneurial business intelligence and green innovation, resulting in a significant indirect effect ($\beta = 0.148$, $p < 0.001$). Moreover, the total effect of entrepreneurial business intelligence on green innovation was positive ($\beta = 0.376$, $p < 0.001$). The findings imply that international banks leveraging data-driven entrepreneurial business intelligence together with sustainability practices are better positioned to enhance green innovation in support of green finance.

Keywords entrepreneurship, business intelligence, green innovation, sustainability, banking

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INTRODUCTION

Growing regulatory pressure and stakeholder expectations have increased the emphasis on the role of the global financial system in promoting sustainable finance, and financial institutions have been assigned the task of ensuring that economic performance is aligned with social and environmental accountability (Arici & Uysal, 2022). The modern financial system is no longer evaluated solely in terms of financial performance but also in terms of its contribution to sustainability-driven innovation (N. Ahmad et al., 2026). The creation of the United Nations' Principles for Responsible Banking and the European Union Green Deal has made it even clearer what role banks should play in promoting sustainability and innovation in the financial system (Adiguzel & Sonmez Cakir, 2025; M. Ahmad et al., 2026). It seems reasonable to examine this issue from the perspective of international banks working in Europe and North America, as they can be considered to function within an infrastructure with highly developed information technology systems and a sustainable

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regulatory environment. This means developing a new paradigm for the financial sphere, in which not only the external aspect of sustainability is considered but also its impact on the performance of financial institutions.

Nevertheless, there are some constraints regarding banks' sustainability operations. From various studies, it is clear that sustainability strategies face different problems such as lack of a structured data system, absence of entrepreneurial orientation, ineffective use of technology, and poor decision-making skills (Al-Khatib, 2022; Baeshen et al., 2021). In such a scenario, sustainability strategies may be more compliance-oriented and symbolic than effectively innovation-oriented, hindering the development of environmentally responsible financial products and services (Tuan, 2025). The idea of green innovation in banks involves creating eco-friendly financial services, products, and systems aimed at lessening environmental harm while still creating value (Al-Swidi et al., 2025). The organizational capabilities related to implementing sustainability strategies and developing green innovation are still theoretically underdeveloped and underexplored.

Simultaneously, the concept of entrepreneurial business intelligence has been framed within the dynamic capabilities framework as a construct emphasizing the integration of business intelligence capabilities with entrepreneurial opportunity recognition to support strategic decision-making (Adiguzel & Sonmez Cakir, 2025; Al-Mamary, 2025). This capability's ability to transform scattered and fragmented data into intelligence has also been associated with increased organizational responses to uncertainty. However, as noted above, existing research has primarily focused on sustainability practices and data intelligence as two separate fields of study. The analytical distinction has led to fragmentation, especially within the banking industry, with regard to the interplay of entrepreneurial intelligence-based data capabilities and sustainability-driven innovation.

As a result, there remains a significant gap in understanding of how the data potential of entrepreneurial business intelligence is associated with green innovation in international banks that deal with complicated rules and growing demands for sustainability (Wreikat & Awamleh, 2025). The lack of integrative empirical studies in these related fields hinders the progress of the dynamic capabilities view.

1. LITERATURE REVIEW AND HYPOTHESES

Entrepreneurial business intelligence is an area connected to data gathering, processing, and analysis, largely for operational efficiency and strategic planning. Entrepreneurial business intelligence has traditionally been applied in more predictable sectors and institutions, but it has become less effective in fields that involve high dynamics and sustainability concerns, such as international banking (Tarek & Adel, 2016). Recent publications highlight the need for banks to move beyond passive data observation and improve efforts toward using data and analytics to identify new opportunities and manage risks and sustainability concerns that can influence and guide innovation-oriented decision-making (Kasasbeh et al., 2021).

Theoretical underpinnings of entrepreneurial business intelligence, which extends traditional business intelligence by integrating analytical capabilities with entrepreneurial opportunity recognition, are embedded within the knowledge-based view and the theory of dynamic capabilities, where the importance of analytical knowledge, organizational flexibility, and the ability of resources to change and achieve sustained competitive advantage is highlighted. The theoretical underpinnings of EBI and applications of the approach towards the bank emphasize the following, including the design of predictive models for green investment, the integration of environmental aspects within risk, and the design of digital platforms for facilitating green investment and carbon-neutral transactions within the banking sector, respectively. At the same time, various theoretical underpinnings have reported the following challenges to the implementation of EBI, including ineffectiveness within the bank and resistance within the bank due to the absence of coherent data, technological resistance,

and ineffectiveness of analytical knowledge towards innovation strategy, respectively (Caseiro & Coelho, 2018).

Green Innovation (GI) can be considered an evolution of the traditional innovation paradigm by including environmental and social concerns while designing products, processes, and services (Schiederig et al., 2012; Tu, 2025). In the case of the banking industry, green innovation involves environmentally sustainable financial instruments such as green bonds, sustainable investment portfolios, ecological and green credit strategies, and energy-efficient online banking systems (Frare & Beuren, 2022; Makhloufi, 2024). Resource-based theory is the most fundamental theoretical framework explaining green innovation and the concept that organizations can gain sustained competitive advantage by creating and sustaining distinctive and imitator-resistant green skills and resources (Zameer et al., 2022; Tuan, 2025). There are empirical findings verifying that green innovation is associated with better organizational outcomes, compliance, trust, adaptability, and resilience to various conditions and risks (M. Ahmad et al., 2026; Al-Abbadi et al., 2025).

However, despite its significance, the formal establishment of green innovation in banks is still unbalanced. Many academic works suggest that banks face problems of unstable sustainability metrics and unsynchronized sustainability technology integration, as well as a lack of analytical platforms supporting environmentally directed innovation (Al-Khatib, 2022; Al-Mamary, 2025). Traditional interpretations of innovation tend to misplace the significance of analytical facilitation in supporting sustainability-led invention, resulting in unsustainable outcomes of green innovation projects (Al-Abbadi et al., 2025; Al-Mamary, 2025). Nevertheless, contemporary scholarship suggests a transition towards data-driven green innovation, in which cutting-edge analytical tools, artificial intelligence, and smart ecosystems shape the structuring of environmentally attuned financial services (Liu et al., 2025). Hence, the demand for green innovation in international banks is not a supplementary or supportive demand but a need to offer a transparent, resilient, and sustainability-driven strategy (Makhloufi, 2024; Schiederig et al., 2012).

Sustainability Practices (SP) are defined as the organizational architecture, policies, and practices that integrate environmental, social, and governance (ESG) considerations within business activities (Alshehhi et al., 2018). The theoretical foundations of sustainability practices are often based on stakeholder theory and corporate sustainability management, which view organizational activities in terms of their alignment and accommodation towards societal expectations (Lawrence et al., 2006; Awamleh et al., 2025a). In the banking industry, sustainability practices can comprise sustainable lending practices, ESG-based risk management, energy-efficient management, sustainable human resource management practices, and effective corporate governance practices (Batista & Francisco, 2018).

Empirical research reveals the positive impact of banks with efficient sustainability governance on their reputation, risk management, and innovative performance, as they outperform their competitors (Jorge et al., 2015; Bautista-Puig and Sanz-Casado, 2021). Sustainability-driven financial organizations are more likely to appeal to SRI followers and the international community in terms of incorporating the UN's Sustainable Development Goals; they can create environmentally responsible financial products (Lawrence et al., 2006). Moreover, the existing literature identifies challenges in the area, such as the absence of a standard for ESG reporting, the absence of a single performance indicator, and the gap in the regulatory environment (Alshehhi et al., 2018).

However, a new wave of research indicates that sustainability practices could play an important mediating role in the relationship between technological/managerial capabilities and the output of sustainable innovation. Although entrepreneurial business intelligence enables banks with the ability to analyze trends and convert data into valuable information for predicting market trends and exploiting green innovation, the effective execution of these analyses largely relies on the sustainability environment of the bank (M. Ahmad et al., 2026; Tuan, 2025). Unless the bank's sustainability strategies are effective, business intelligence information could be inadequately exploited or cannot be easily converted into tangible green innovation (Makhloufi, 2024). From an organizational sys-

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tems standpoint, the value added by technology is improved when it is integrated with appropriate cultural and process structures (Liu et al., 2025; Amore & Bennedsen, 2016). Sustainability processes can thereby provide incentives and alignments that would encourage managerial action based on BI information that strives for environmental innovation (Suki et al., 2023; Alarabiat et al., 2025). Hence, organizations that have a high level of developed sustainability processes are likely to turn entrepreneurial intelligence into environmentally responsible innovation, whereas organizations without such processes may not be able to tap the potential of EBI (N. Ahmad et al., 2026; Al-Khatib, 2022). Collectively, the literature emphasizes the significance of entrepreneurial business intelligence, green innovation, and sustainability practices within the international banking industry.

However, existing research has examined each construct separately, offering little empirical information on their interrelationships and mediating mechanisms simultaneously. Specifically, the importance of sustainability practices in mediating the relationship between entrepreneurial business intelligence and green innovation has not been explored adequately. Consequently, there is a requirement for a comprehensive model that describes the relationship between entrepreneurship skills based on data, sustainability practices, and green innovations. Based on the discussion above, the research study to be carried out will focus on the relationship between business intelligence skills for entrepreneurs and green innovations in the international banking industry and how the process will be mediated by sustainability practices. The research hypotheses to be developed are as follows:

H1: Entrepreneurial business intelligence positively affects green innovation.

H2: Entrepreneurial business intelligence positively affects sustainability practices.

H3: Sustainability practices positively affect green innovation.

H4: Sustainability practices positively mediate the relationship between entrepreneurial business intelligence and green innovation.

2. METHODOLOGY

This study employed a quantitative, cross-sectional research design to examine the relationships among Entrepreneurial Business Intelligence (EBI), Sustainability Practices (SP), and Green Innovation (GI) in international banks operating in Europe and North America. Sustainability Practices were specified as a mediating construct in the relationship between EBI and GI. Partial least squares structural equation modeling (PLS-SEM) was selected because it is suitable for estimating predictive models involving multiple latent constructs, direct effects, indirect effects, and mediation relationships. The conceptual model, informed by the Resource-Based View and Dynamic Capabilities Theory, explains how valuable organizational resources, knowledge-based capabilities, and adaptive processes enable organizations to integrate sustainability considerations and foster environmentally oriented innovation. The main data collection was conducted between July and August 2025. The individual managerial staff was the unit of analysis. Therefore, the indicators represented managers' impressions of their banks' entrepreneurial business intelligence, sustainability practices, and green innovation activities, instead of confirmed organizational features.

The target population referred to managerial-level employees working in seven international banks, including HSBC, Citibank, Standard Chartered Bank, Deutsche Bank, Barclays Bank, Bank of America, and BNP Paribas. Survey respondents were selected from branches and regional offices operating in Germany, France, the United Kingdom, and the United States. Respondents had to be managers/supervisors and have knowledge of business intelligence, analytics, sustainability strategy, risk management, green innovation, or similar practices. This sample included branch managers, department managers, risk managers, sustainability managers, and strategy managers dealing with corporate banking, retail banking, risk management, sustainability, and strategy & innovation.

Purposive sampling, together with controlled snowball sampling techniques, was used to identify respondents who were information-rich and whose professional obligations were associated

with the studied constructs. Initial respondents were recruited through LinkedIn professional contacts, alumni contacts, and collaboration between academia and industry. These respondents were further asked to refer to other managers meeting the same criteria within the participating banks.

A total of 400 questionnaires were successfully delivered, and 384 were returned, which is an initial response rate of 96.0%. After data screening, 6 questionnaires were discarded due to missing answers, and the final sample consisted of 378 valid cases, which is a response rate of 94.5%. Such a high response rate could be explained by targeted sampling techniques and professional referrals. Repeated participation was reduced by providing a unique survey link for each participant and asking participants to fill in the questionnaire only once, as well as by screening for duplicate entries in the dataset. As purposive and snowball sampling techniques are non-probability techniques, findings should be generalized carefully beyond the participating banks, managerial groups, and countries. In addition, as the respondents were clustered within 7 banks, the issue of organization clustering was taken into consideration in the robustness analysis. Seven banks participated in the study, and they were represented by 12 operational branches in

Table 1. Organizational and demographic characteristics of the respondents

Characteristic	Category	n	%
Bank	HSBC	96	25.397
Bank	Bank of America	66	17.460
Bank	Deutsche Bank	54	14.286
Bank	BNP Paribas	46	12.169
Bank	Barclays	44	11.640
Bank	Standard Chartered	36	9.524
Bank	Citibank	36	9.524
Country	United States	102	26.984
Country	Germany	96	25.397
Country	United Kingdom	92	24.339
Country	France	88	23.280
Department	Corporate Banking	102	26.984
Department	Retail Banking	80	21.164
Department	Risk Management	71	18.783
Department	Sustainability	65	17.196
Department	Strategy & Innovation	60	15.873
Position	Department Head	113	29.894
Position	Branch Manager	86	22.751
Position	Risk Manager	71	18.783
Position	Sustainability Manager	56	14.815
Position	Strategy Manager	52	13.757
Experience	1–5	81	21.429
Experience	6–10	117	30.952
Experience	11–15	113	29.894
Experience	16+	67	17.725
Branch	Frankfurt	53	14.02
Branch	New York	53	14.02
Branch	Paris	48	12.70
Branch	London	45	11.90
Branch	Chicago	28	7.41
Branch	Manchester	27	7.14
Branch	Berlin	24	6.35
Branch	La Défense	23	6.08
Branch	San Francisco	21	5.56
Branch	Birmingham	20	5.29
Branch	Munich	19	5.03
Branch	Lyon	17	4.50

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Germany, France, the United Kingdom, and the United States. Table 1 shows the distribution of respondents by bank, branch, country, department, position, and experience.

As seen in Table 1, the sample comprised seven international banks, 12 operational branches, and four countries, as well as different managerial positions, functional departments, and professional experience. The diversity of the sample gave rise to a proper empirical setting to investigate the hypotheses regarding the links between EBI, SP, and GI.

For collecting data, we used a structured questionnaire based on the adapted measurement items taken from previous studies and adjusted for international banks operating in Europe and North America. Entrepreneurial Business Intelligence was measured through the items adapted from the scales of Almazmomi et al. (2022), Caseiro and Coelho (2018), and Kasasbeh et al. (2021). The adapted items captured the utilization of business intelligence and analytics in terms of knowledge generation, managerial decision-making, predictive analysis, and entrepreneurial opportunities. Sustainability practices were measured through the items adapted mainly from Awamleh et al. (2025a); at the same time, the items also took into account the construct's contextualization proposed by Bautista-Puig and Sanz-Casado (2021). Adapted items reflected the development of sustainability-oriented policies, commitments of managers and employees, organizational culture, responsibility towards the environment, and integrating sustainability aspects into banking operations. Green innovation was measured through the items adapted from Zameer et al. (2022) and Al-Swidi et al. (2025), reflecting environmentally sustainable financial products and services, green investment opportunities, environmental aspects of financial decisions, and technological solutions aimed at improving resource and energy efficiency.

The questionnaire was created in English since it is widely used as the working language of the multinational banks taking part in the research; hence, there was no need for translation and back-translation. To establish content validity and relevance to the context of the study, the instrument was evaluated by three experts in strategic management and sustainability. Before conducting the survey, the questionnaire was pretested on 30 managers employed in international banks. As a result, some linguistic adjustments were made in response to feedback received in the process of reviewing and testing the questionnaire. At the same time, no conceptual changes were introduced in the items. The items representing all constructs were measured on a five-point Likert scale (1-"strongly disagree" to 5-"strongly agree"). EBI, SP, and GI were specified as reflective constructs because their indicators were treated as manifestations of the underlying latent variables.

EBI, SP, and GI were specified as reflective constructs because their indicators were treated as manifestations of the underlying latent variables. Although these constructs have sometimes been discussed in the literature as multidimensional concepts, the present study operationalized each construct as a first-order reflective latent variable. This decision was based on the measurement purpose of the study, as the adapted items were intended to capture respondents' overall perceptions of each construct rather than to estimate theoretically distinct dimensions as separate lower-order components. Accordingly, the indicators were treated as correlated manifestations of a common underlying perception, rather than as formative dimensions that jointly create the construct. This specification was also consistent with the validated scales from which the measurement items were adapted.

Although Entrepreneurial Business Intelligence, Sustainability Practices, and Green Innovation have been considered multidimensional constructs at times, the current study aimed to measure the managers' perception of these organizational phenomena and not the theoretical dimensions of the constructs themselves. Therefore, the constructs were measured using a first-order reflective latent variable approach based on the original measurement scales for each construct. The estimation of a higher-order formative model would be justified only in the case of theoretical grounds and multidimensional measures for each construct.

Because the predictor, mediator, and outcome variables were collected from the same respondents through a single questionnaire, procedural and statistical measures were used to address po-

tential common method bias. Respondents were assured that participation was anonymous and confidential, and the questionnaire emphasized that there were no correct or incorrect answers. These procedures were designed to lower evaluation apprehension, social desirability bias, and response consistency artifacts. Further diagnostic procedures such as Harman's single-factor test and variance inflation factors (collinearity) were run as part of supplementary statistical analysis, with the outcomes of the tests presented in the empirical section of this paper.

Participants were asked to provide their voluntary participation in the study and provide informed consent before starting the questionnaire. The purpose of the study, the scientific usage of the collected data, participants' rights to withdraw at any moment, and the confidentiality of their responses were explained to the participants of the survey. No personally identifiable information was collected, and the analysis and presentation of results were carried out in aggregated form. Ethical approval was not needed according to the institutional guidelines since the study included anonymous voluntary survey responses, no collection of personally identifying information, and no risks to participants other than those inherent in routine daily activities.

The data set was analyzed with the help of SmartPLS 4 using a two-step PLS-SEM approach. The reflective measurement model was analyzed for indicator reliability, internal consistency reliability, convergent validity, and discriminant validity on the basis of indicator loadings, Cronbach's alpha, composite reliability, average variance extracted, heterotrait-monotrait ratio, and collinearity diagnostics. Next, the structural model was assessed for path coefficients, significance of the paths, collinearity, explanatory power, effect sizes, and predictive relevance. The statistical significance of direct and indirect effects and the mediating role of sustainability practices were estimated using bootstrapping (N = 5,000). Further analysis was carried out on the basis of R^2, f^2, Q^2, out-of-sample prediction (PLSpredict), measurement invariance test (MICOM), robustness test for clustering, control variable analysis, sensitivity analysis, and comparison with the alternative causal model.

3. RESULTS

The analysis adopted the prescribed two-stage PLS-SEM process. The measurement model was evaluated first in order to ensure that the measurement scales were reliable and valid; then the structural model and hypothesis testing took place. Other tests were done on the model to evaluate mediation, explanatory/predictive performance, measurement invariance, clustering, control variables, sensitivity, and alternative model specifications. As described in the methodology section, the unit of analysis was the individual manager within the bank, and all the latent variables represent the managers' perceptions of the bank, specifically regarding the bank itself.

3.1. Common method bias assessment

While a number of procedural techniques have been utilized throughout the development of the survey and data gathering processes, further statistical procedures were carried out to check the impact of common method bias (CMB). Both Harman's one-factor test and the collinearity VIF technique were used as supporting measures. As shown in Table 2, the first unrotated factor accounts for less than 50 percent of the total variance, and at the same time, all full-collinearity VIFs stay significantly below the threshold level of 3.30. Hence, common method bias cannot be considered a threat to the validity of the relationships found.

Table 2. Common method bias assessment

Assessment	Result	Criterion
Harman single factor	38.640	< 50%
Full collinearity VIF – EBI	1.226	< 3.30
Full collinearity VIF – SP	1.383	< 3.30
Full collinearity VIF – GI	1.395	< 3.30

3.2. Item descriptive statistics

Based on Table 3, the descriptive statistics at the item level revealed that the average scores fell in the range of 3.950 to 4.114, implying that the participants held positive perceptions about entrepreneurial business intelligence, sustainability practices, and green innovation. The standard deviations were in the range of 0.696 to 0.761, imply-

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ing moderate dispersion of results. Additionally, the values for skewness and kurtosis were within the acceptable limits for univariate normality; thus, there was no indication of deviation from the normal distribution. Although the assumption of multivariate normality is not necessary for PLS-SEM, these descriptive statistics add more strength to the validity of the data.

Table 3. Item-level descriptive statistics

Item	Mean	SD	Skewness	Kurtosis
EBI1	4.108	0.696	−0.292	−0.426
EBI2	4.090	0.697	−0.360	−0.122
EBI3	4.111	0.731	−0.380	−0.418
EBI4	4.077	0.726	−0.452	−0.020
EBI5	4.114	0.729	−0.385	−0.395
EBI6	4.098	0.734	−0.357	−0.468
EBI7	4.090	0.734	−0.426	−0.208
SP1	4.005	0.710	−0.097	−0.750
SP2	4.045	0.718	−0.283	−0.387
SP3	4.048	0.719	−0.329	−0.267
SP4	4.011	0.717	−0.232	−0.425
SP5	4.045	0.721	−0.323	−0.291
SP6	4.005	0.714	−0.272	−0.273
GI1	3.974	0.713	−0.182	−0.434
GI2	3.960	0.761	−0.332	−0.292
GI3	3.963	0.724	−0.239	−0.320
GI4	3.952	0.716	−0.323	−0.037
GI5	3.992	0.752	−0.288	−0.428
GI6	3.950	0.736	−0.202	−0.449
GI7	3.966	0.707	−0.358	0.350
GI8	3.963	0.724	−0.197	−0.429
GI9	3.974	0.717	−0.222	−0.351

3.3. Measurement model assessment

Reflection on the measurement model reliability and convergent validity of the reflective measurement model has been tested by analyzing indicator reliability, internal consistency, and convergent validity. The indicator reliability test has been done based on the outer loadings, while the internal consistency has been checked with Cronbach's alpha, rho_A, and composite reliability (CR). The convergent validity has been measured based on the average variance extracted (AVE). As shown in Table 4, all indicators that have been retained for the model had satisfactory outer loadings, while the values of Cronbach's alpha, rho_A, and CR were higher than the threshold value of 0.70. Moreover, the AVE values for all constructs exceeded 0.50.

Table 4. Measurement model assessment

Construct	Item	Outer loading	Cronbach alpha	rho_A	CR	AVE
EBI	EBI1	0.787	0.898	0.914	0.920	0.621
	EBI2	0.821				
	EBI3	0.729				
	EBI4	0.792				
	EBI5	0.795				
	EBI6	0.824				
	EBI7	0.763				
SP	SP1	0.839	0.894	0.915	0.919	0.654
	SP2	0.859				
	SP3	0.797				
	SP4	0.820				
	SP5	0.731				
	SP6	0.801				
GI	GI1	0.763	0.923	0.934	0.936	0.620
	GI2	0.749				
	GI3	0.813				
	GI4	0.751				
	GI5	0.868				
	GI6	0.798				
	GI7	0.759				
	GI8	0.812				
	GI9	0.762				

3.4. Discriminant validity assessment

Discriminant validity was examined using both the Fornell–Larcker criterion and the heterotrait–monotrait ratio (HTMT), which are widely recommended for evaluating construct distinctiveness in PLS-SEM. According to the Fornell–Larcker criterion, the square root of the AVE for each construct exceeded its correlations with the remaining constructs, indicating satisfactory discriminant validity. In addition, all HTMT values and their bootstrapped confidence intervals remained below the recommended threshold, providing further evidence that the latent constructs are empirically distinct from one another. The results presented in Tables 5 and 6 therefore confirm adequate discriminant validity across all study constructs.

Table 5. Fornell–Larcker criterion

Construct	EBI	SP	GI
EBI	0.788		
SP	0.365	0.809	
GI	0.376	0.488	0.787

Table 6. HTMT ratios and bootstrap confidence intervals

Pair	HTMT	2.5%	97.5%
EBI-SP	0.399	0.291	0.491
EBI-GI	0.406	0.321	0.495
SP-GI	0.528	0.439	0.611

3.5. Collinearity assessment

Before estimating the structural relationships, predictor collinearity was examined using inner-model variance inflation factor (VIF) values. As reported in Table 7, all VIF values were substantially below the recommended threshold of 3.30, indicating that multicollinearity was not a concern. Consequently, the estimated path coefficients can be interpreted without evidence that excessive predictor collinearity distorted the structural relationships.

Table 7. Inner-model VIF values

Predictor relationship	VIF
EBI → SP	1.000
EBI → GI	1.154
SP → GI	1.154

3.6. Clustering diagnostics

Because the respondents were nested within banks and countries, clustering diagnostics were examined to evaluate the potential influence of organizational grouping on the estimated relationships. As presented in Table 8, the design effect exceeded the recommended threshold only for Entrepreneurial Business Intelligence (EBI) at the bank level, whereas all remaining constructs exhibited design effects close to or equal to 1.00. Similarly, ICC (1) values were generally low across the examined clusters. Although the bank-level design effect for EBI exceeded the conventional threshold, subsequent bank-adjusted sensitivity analyses produced substantively similar coefficients, suggesting that the primary conclusions were robust to organizational clustering.

Table 8. ICC and design-effect diagnostics

Construct	Cluster	ICC (1)	Average cluster size	Design effect
EBI	Bank	0.049	52.801	3.564
EBI	Country	0.002	94.406	1.186
SP	Bank	0.000	52.801	1.000
SP	Country	0.000	94.406	1.000
GI	Bank	0.000	52.801	1.000
GI	Country	0.000	94.406	1.000

Even though the bank design effect for the entrepreneurial business intelligence was above the acceptable level, the results of the adjusted sensitivity analysis at the bank level yielded very similar path coefficients with identical inferences. Organizational clustering, therefore, did not affect the inference drawn from the estimated structural models, but future research involving more organizations might find the multilevel approach useful.

3.7. Structural model and hypotheses

After the validation of the appropriateness of the measurement model, the structural models were analyzed using bootstrapping. From the results reflected in Table 9 and Figure 1, it is evident that all the postulated relationships were positive and significant. There was a significant positive influence of Entrepreneurial Business Intelligence (EBI) on Sustainability Practices (SP), validating H2. Similarly, there was a positive and significant relationship between EBI and Green Innovation (GI), thus validating H1. Moreover, there was a positive and significant relationship between sustainability practices and green innovation, thus validating H3. Thus, it is evident from the above results that entrepreneurial business intelligence positively influences green innovation and enhances sustainability practices in international banks.

Table 9. Structural path estimates

Path	Beta	SE	t	p	2.5%	97.5%	Decision
EBI → SP	0.365	0.043	8.503	<0.001	0.281	0.452	Supported
EBI → GI	0.228	0.041	5.619	<0.001	0.143	0.298	Supported
SP → GI	0.405	0.044	9.224	<0.001	0.330	0.491	Supported

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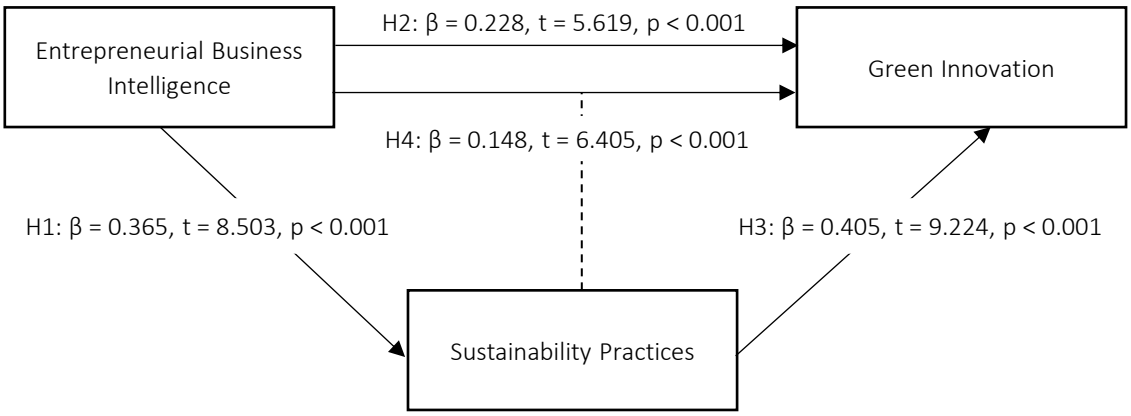

Figure 1. Structural model

Table 10. Indirect effect and mediation assessment

Indirect path	Indirect effect	SE	t	p	2.5%	97.5%	Total effect	VAF
EBI → SP → GI	0.148	0.023	6.405	<0.001	0.106	0.197	0.376	0.394

3.8. Mediation analysis

In subsequent stages, the mediation of sustainability practices in the relationship between entrepreneurial business intelligence and green innovation was examined. Based on the results presented in Table 10 and Figure 1, the indirect effect turned out to be positive and statistically significant, thus proving that sustainability practices serve as one of the channels through which entrepreneurial business intelligence affects green innovation. Since both the direct and indirect effects were found to be statistically significant, the study results imply partial mediation. The VAF value also proves that sustainability practices constitute a considerable part of the total effect. Therefore, H4 was supported.

3.9. Explanatory power and effect sizes

The quality of explanation and prediction made by the structural model was evaluated based on the coefficient of determination (R^2), predictive relevance (Q^2_predict), and effect size (f^2). The results, reported in Tables 11 and 12, show that the model provides satisfactory explanatory quality regarding both endogenous constructs, with Q^2_predict being positive for all constructs, showing acceptable predictive relevance. Furthermore, the effect sizes estimated are small to medium in accordance with standard criteria, implying that entrepreneurial business intelligence and sustainability practices provide significant contributions to explain the variation in the endogenous constructs (Sarstedt et al., 2024).

Table 11. Explanatory and predictive relevance

Endogenous construct	R2	Q2_predict
SP	0.133	0.124
GI	0.283	0.276

Table 12. Effect sizes

Relationship	f2
EBI → GI	0.063
SP → GI	0.198
EBI → SP	0.154

3.10. Sensitivity and control-variable analyses

To test the strength of the relationships, further analysis was conducted using control variables specific to the banks and countries, as well as using a model based on organizational and managerial variables. According to Tables 13 and 14, there were no significant differences in the path coefficients across all models. Furthermore, the control variables did not exhibit statistically significant effects on Green Innovation. These findings indicate that the observed relationships

among Entrepreneurial Business Intelligence, Sustainability Practices, and Green Innovation are robust and are not driven by the organizational or demographic characteristics included in the analysis (Sarstedt et al., 2024).

Table 13. Bank- and country-adjusted sensitivity analysis

Specification	EBI → GI	SP → GI	R2
Base model	0.228	0.405	0.283
Bank-adjusted	0.222	0.411	0.293
Country-adjusted	0.233	0.405	0.287

3.11. Measurement invariance (MICOM-oriented assessment)

Measurement invariance across countries was tested as an additional robustness analysis. As shown in Table 15, compositional correlations were consistently equal to 1.000 across all country comparisons, whereas the permutation tests for equality of means and variances supported partial measurement invariance. These findings provide evidence of partial measurement invariance, supporting cautious comparison of the structural relationships across the participating countries (Sarstedt et al., 2024).

3.12. Predictive assessment

The predictive capability of the proposed model was further evaluated using the PLSpredict procedure. As per the results shown in Table 16, all the endogenous variables have shown a positive Q^2_predict value, which means that the model has a satisfactory level of predictive power for out-of-sample prediction. RMSE and MAE values for the model show satisfactory predictive power for the proposed model (Sarstedt et al., 2024).

Table 16. PLSpredict-style construct-score assessment

Construct	Q2_predict	RMSE	MAE
SP	0.124	0.935	0.757
GI	0.276	0.850	0.676

Table 14. Control-variable model

Predictor	Beta	t	p
EBI	0.225	4.565	<0.001
SP	0.415	8.512	<0.001
Bank_Bank of America	0.043	<0.001	1.000
Bank_Barclays	0.062	0.185	0.853
Bank_Citibank	0.085	<0.001	1.000
Bank_Deutsche Bank	–0.261	–1.008	0.314
Bank_HSBC	0.077	0.413	0.680
Bank_Standard Chartered	0.022	0.064	0.949
Country_Germany	0.186	0.983	0.326
Country_United Kingdom	0.093	0.329	0.743
Country_United States	0.128	<0.001	1.000
Position_Department Head	0.044	0.357	0.721
Position_Risk Manager	–0.021	–0.148	0.882
Position_Strategy Manager	0.050	0.332	0.740
Position_Sustainability Manager	0.007	0.048	0.962

Table 15. Country-level measurement invariance assessment

Construct	Comparison	Compositional correlation	p (means)	p (variances)	Conclusion
EBI	Germany vs France	1.000	0.880	0.108	Partial invariance
EBI	Germany vs United Kingdom	1.000	0.228	0.402	Partial invariance
EBI	France vs United Kingdom	1.000	0.344	0.296	Partial invariance
SP	Germany vs France	1.000	0.568	0.306	Partial invariance
SP	Germany vs United Kingdom	1.000	0.392	0.250	Partial invariance
SP	France vs United Kingdom	1.000	0.780	0.908	Partial invariance
GI	Germany vs France	1.000	0.980	0.588	Partial invariance
GI	Germany vs United Kingdom	1.000	0.562	0.892	Partial invariance
GI	France vs United Kingdom	1.000	0.516	0.528	Partial invariance

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3.13. Alternative model comparison

In addition, the proposed conceptual model was compared with another causal model to evaluate the relative feasibility of the suggested mediation process. As shown in Table 17, both models achieved similar goodness-of-fit indices, although the alternative model achieved a slightly smaller AIC index. However, despite the fact that the alternative model provided a slightly smaller AIC index, the difference between the models was not significant. Consequently, the theoretical model was chosen as the main one due to its consistency with the proposed conceptual framework and mediation process (Sarstedt et al., 2024).

Table 17. Alternative model comparison

Model	SSE	AIC
Hypothesized: EBI → SP → GI	596.940	–168.586
Alternative: EBI → GI → SP	596.465	–169.188

4. DISCUSSION

Entrepreneurial business intelligence Research has demonstrated a positive correlation between entrepreneurial business intelligence and sustainability practices, as well as perceived green innovation. This research aims to demonstrate that entrepreneurial business intelligence is positively correlated with sustainability practices and perceived green innovation. The positive correlation between entrepreneurial business intelligence and sustainability practices, in contrast to its correlation with green innovation, indicates that entrepreneurial business intelligence primarily enhances the capabilities of organizations implementing sustainability initiatives, even if those capabilities do not directly lead to innovation outcomes. It aligns with previous research on the importance of business intelligence as a tool to facilitate strategic decisions and organizational flexibility, which is a necessary condition for organizational development in line with sustainability (Al-Abbadi et al., 2025; Al-Mamary, 2025; Adiguzel & Sonmez Cakir, 2025).

It can be further observed that sustainability practices are positively correlated with green innovation and partially mediate the link between entrepreneurial business intelligence and green innovation. This means sustainability practices act as organizational mechanisms that transform an organization's analytical capabilities into environmental innovations. This corresponds to previous studies on the role of sustainability-oriented organizational governance and policies as factors that help organizations to transform their technological capabilities into innovation outcomes (Batista & Francisco, 2018; Chen, 2008; Chen et al., 2012; Linnenluecke et al., 2009; Liu et al., 2025). However, as cross-sectional perceptual data were used, the mediation is only an indicator of correlation and not a factor of causality.

The current study contributes to the body of literature in its integration of entrepreneurial business intelligence, sustainability practices, and green innovation in one empirical framework in the field of international banking. In previous studies, all three concepts were usually examined separately; however, the results of the current study show that sustainability practices are an organizational mechanism that links entrepreneurial business intelligence and perceived green innovation (Ramadhani et al., 2025; Suki et al., 2023; Schiederig et al., 2012). Consequently, the study offers further empirical evidence to substantiate the synergistic relationship between analytical capabilities and sustainability-oriented organizational processes in elucidating green innovations (Jorge et al., 2015; Frare & Beuren, 2022).

For managers of international banks, the findings of the current study are a reminder that entrepreneurial business intelligence will be more valuable when combined with sustainability strategy, governance mechanisms, and organizational processes rather than when applied only as a technological capability. The alignment of analytical capabilities with the sustainability objectives will not only promote environmentally responsible financial services but also contribute to sustainable goals (Ramadhani et al., 2025; Suki et al., 2023; Tuan, 2025).

CONCLUSION

The aim of the study was to analyze the associations between entrepreneurial business intelligence, sustainability practices, and green innovation in international banks in Europe and North America. It has

been shown that entrepreneurial business intelligence is positively correlated with perceived sustainability practices and green innovation. Furthermore, sustainability practices mediate the association between entrepreneurial business intelligence and green innovation, thus pointing to the significance of sustainability practices as an organizational mechanism linking analytical skills and environmental innovation. One of the main strengths of the study lies in examining the mediating role of sustainability practices in the relationship between entrepreneurial business intelligence and green innovation in the context of international banking. From a practical perspective, the findings suggest that integrating entrepreneurial business intelligence with sustainability practices may support perceived green innovation.

Nevertheless, the findings should be interpreted in light of several limitations. First, the cross-sectional design does not permit causal inference. Second, the use of non-probability sampling limits the generalizability of the findings beyond the participating banks and respondents. Third, the study relied on managers' self-reported perceptions, which may be influenced by social desirability bias despite the procedural measures implemented to reduce its potential impact. Finally, although several procedural and statistical remedies were applied to mitigate common method bias, the data were collected from a single source at one point in time. Therefore, common response tendencies cannot be completely ruled out, and the findings should be interpreted as perception-based rather than objective organizational assessments.

AUTHOR CONTRIBUTIONS

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APPENDIX A

The questionnaire consisted of measurement items adapted from previously validated scales. All items were measured using a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"). Table A1 presents the complete measurement items together with their original sources and indicates whether each item was adopted directly or adapted to the context of international banking.

Table A1. Measurement scale

Construct	Items	Primary source(s)	Status
Entrepreneurial Business Intelligence	Our bank transforms business information into strategic knowledge.	Almazmomi et al. (2022); Caseiro and Coelho (2018); Kasasbeh et al. (2021)	Adapted
	Employees share business intelligence across departments.		
	Our bank uses predictive analytics to anticipate customer needs.		
	Predictive analytics support strategic decisions.		
	Business intelligence improves market trend forecasting.		
	Business intelligence enables our bank to identify emerging entrepreneurial opportunities.		
	Managers rely on business intelligence to evaluate and exploit new business opportunities.		
Green Innovation	Our bank develops environmentally sustainable financial products.	Zameer et al. (2022); Al-Swidi et al. (2025)	Adapted
	Environmental considerations guide new product development.		
	The bank continuously improves environmentally friendly services.		
	The bank supports environmentally sustainable investments.		
	Environmental criteria guide investment decisions.		
	The bank allocates resources to sustainable initiatives.		
	The bank adopts digital technologies to improve energy efficiency.		
	Digital banking reduces resource consumption.		
	Technological innovation improves operational energy efficiency.		
Sustainability Practices	Sustainability principles guide the bank's strategic policies.	Awamleh et al. (2025a); Bautista-Puig and Sanz-Casado (2021)	Adapted
	Senior management supports sustainability initiatives.		
	Employees participate in sustainability activities.		
	Environmental responsibility is embedded in the bank's culture.		
	Sustainability is integrated into daily operations.		
	Operational processes are continuously improved to reduce environmental impacts.		

Note: Measurement items of each construct were selected from the respective validated scales mentioned in the "Primary source(s)" column. Since the scale has been constructed through combining and contextualizing items from different validated scales, citations are provided at the construct level, not for each item separately. None of the measurement items have been newly created. Wording changes have been made only for contextual fit into the international banking setting.