

Linking Sustainable Financing Mechanisms to Circular Performance and Competitiveness in Recycled Building Material Manufacturing

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Abstract

The study examined the influence of sustainability-linked financial instruments specifically green bonds and sustainability-linked loans on the cost of capital, circular performance, product innovation, and competitiveness of recycled-material manufacturers in Jordan. Positioned within the theoretical frameworks of sustainability-linked finance, the resource-based view, and signalling theory, the research explored how financial mechanisms tied to circular performance indicators enhance both financial and operational outcomes in the manufacturing sector. The study focuses on manufacturers utilizing recycled building materials such as recycled steel and construction and demolition (C&D) aggregates that form the foundation of sustainable construction practices in emerging markets. A quantitative, explanatory research design was adopted, involving survey data from 89 Jordanian manufacturers using recycled steel, construction aggregates, and other circular materials. Analytical methods included multiple regression, mediation modelling, stochastic simulation of policy scenarios, and machine-learning-driven sentiment analysis to assess investor perceptions. The results indicated that firms utilizing sustainable financing instruments achieved a significantly lower cost of capital, improved circular performance, and higher product innovation levels compared to conventionally financed firms. Circular performance partially mediated the relationship between sustainable financing and competitiveness, while positive investor sentiment strengthened this association. Simulation results further demonstrated that policy incentives such as carbon credits and green credit schemes enhanced financial efficiency and competitiveness under uncertainty. The study concluded that sustainability-linked finance functions not only as a funding mechanism but also as a strategic lever for innovation and competitiveness in circular manufacturing. It provides empirical evidence that financial and environmental objectives can be mutually reinforcing within emerging market contexts such as Jordan.

Keywords: *Sustainable finance, Green bonds, Sustainability-linked loans, Circular economy, Recycled-Material Building.*

Introduction

The global construction and manufacturing industries are undergoing a profound transformation driven by the dual imperatives of sustainability and financial innovation. The emergence of sustainable financing mechanisms particularly green bonds and sustainability-linked loans (SLLs) has redefined how firms access capital and demonstrate environmental accountability (Nasir & Ahmed, 2024; Mohammad et al., 2024a). These instruments link financial performance with sustainability outcomes, creating a

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structural connection between capital markets and environmental responsibility. According to the Climate Bonds Initiative, the global green bond market surpassed USD 500 billion in new issuances in 2022, reflecting investors' growing preference for environmentally aligned investments (Tolliver et al., 2019; Mohammad et al., 2025a). Simultaneously, the circular economy has become central to the discourse on sustainable development, especially in the construction sector, which accounts for approximately 40% of global material use and 30% of waste generation (Karaca et al., 2024; Mohammad et al., 2025b). Manufacturers of recycled materials such as recycled steel and construction and demolition aggregates play a pivotal role in reducing the sector's environmental footprint. However, transitioning to circular production models requires substantial capital investment and financial restructuring. Traditional financing mechanisms often fail to accommodate the long-term, non-linear returns of circular initiatives (Saarinen & Aarikka-Stenroos, 2022). This creates a need for sustainability-linked financing models that align investors' expectations with firms' environmental performance.

In emerging economies such as Jordan, the integration of sustainable financing with circular manufacturing remains in its early stages. The country's construction sector is expanding rapidly due to infrastructure investments and urbanization, yet it faces mounting challenges related to resource depletion, carbon emissions, and waste management. Recent policy frameworks such as Jordan's National Green Growth Plan (2021–2030) emphasize circular production, but the private sector's capacity to mobilize green finance remains limited (Shalamai, 2024; Mohammad et al., 2024b). This contextual gap highlights the relevance of exploring how sustainability-linked financing instruments can support recycled-material manufacturers in achieving financial and operational competitiveness. As (Odell & Ali, 2016) noted, aligning financial structures with environmental KPIs is particularly vital in emerging markets, where regulatory systems and investor ecosystems are still developing. Jordan thus represents a unique empirical setting for analysing how sustainable financing instruments shape firm-level performance and strategic orientation in the circular manufacturing domain.

Despite the global rise of green bonds and SLLs, their direct effects on manufacturers' competitiveness particularly those engaged in recycled-material production remain underexplored. The majority of prior research has focused on macro-level financial performance or capital market impacts (Hermundsdottir & Aspelund, 2022; Mei et al., 2024; Mohammad et al., 2024c), leaving a gap in understanding the firm-level mechanisms through which sustainable financing influences operational efficiency, innovation, and market positioning. Moreover, while sustainability-linked finance theoretically reduces firms' cost of capital by rewarding environmental performance (Vulturius et al., 2022; Mohammad et al., 2025c), empirical validation in developing economies remains scarce. There is also limited research integrating behavioural finance perspectives, such as investor sentiment, which significantly shape firm reputation and access to green capital. Thus, the research problem centers on understanding how sustainability-linked financial instruments influence the cost of capital, circular performance, innovation capacity, and competitiveness of recycled-material manufacturers, within a context of evolving investor behaviour and policy support in Jordan.

This study contributes to both academic scholarship and managerial practice. Academically, it extends sustainable finance theory by integrating financial, operational, and behavioural perspectives into a unified analytical model. While prior studies (Kumar et al., 2023; Taera & Lakner, 2025; Mohammad et al., 2025d) established that green finance promotes innovation and cost efficiency, few have examined how these dynamics manifest in circular-material manufacturing within developing economies. Managerially, the study offers strategic guidance for firms, investors, and policymakers. By quantifying how sustainability-linked finance affects competitiveness, it informs corporate investment strategies, supports investors' ESG portfolio decisions, and aids policymakers in designing regulatory frameworks for green finance. At a broader level, the study's focus on Jordan adds empirical depth to the global discourse on green industrialization, contributing to international efforts to align financial systems with the United Nations Sustainable Development Goals (SDGs) particularly Goals 9 (Industry, Innovation, and Infrastructure), 12 (Responsible Consumption and Production), and 13 (Climate Action).

The novelty of this research lies in its multidimensional integration of sustainable finance and circular manufacturing within an emerging market context. Unlike prior studies that treat green finance as a macroeconomic phenomenon, this study adopts a firm-level perspective to explore how financing mechanisms influence cost structures, innovation behaviour, and competitive advantage. It uniquely incorporates investor sentiment analysis using machine learning-based sentiment modelling to capture the behavioural dimension of sustainable finance. This interdisciplinary approach, blending financial modelling, stochastic simulation, and text analytics, provides a more holistic understanding of how

financial, operational, and perceptual variables interact in sustainability-linked ecosystems. The positioning of this research is interdisciplinary, drawing from finance, environmental economics, and strategic management. By merging sustainable finance theory with the Resource-Based View (RBV) (Miller, 2019) and Signalling Theory (Connelly et al., 2024), the study conceptualizes sustainability-linked finance as both a strategic resource and a market signal. This positioning situates the research at the intersection of financial innovation and industrial sustainability, contributing new insights into how emerging economies can leverage green finance to enhance circular competitiveness.

Literature Review

Green bonds and sustainability-linked loans (SLLs) have gained prominence as innovative mechanisms to integrate environmental accountability into financial markets. According to (Jain, 2025), green bonds represent fixed-income securities earmarked for environmentally beneficial projects, while sustainability-linked loans tie borrowing costs directly to the borrower's sustainability performance. Both instruments operationalize environmental goals by embedding measurable key performance indicators (KPIs) into financial agreements. Empirical research has shown that the issuance of green bonds reduces firms' financing costs and enhances their reputation among investors. (Lu, 2021) found that firms issuing green bonds experience improved stock performance and investor recognition due to the credibility signals attached to verified sustainability commitments. Similarly, (Gibbs & Tiftik, 2025) emphasized that these instruments mobilize private capital toward climate-aligned investments, particularly in sectors with high material consumption such as construction and manufacturing. For developing economies, (Taera & Lakner, 2025) argued that sustainability-linked financial products can serve as vehicles for industrial transformation, especially when integrated into policy frameworks encouraging circular economy transitions. However, empirical work on how such instruments directly influence cost of capital and firm competitiveness in emerging markets remains limited, creating a significant gap for contextual exploration in Jordan and the Middle East.

The cost of capital is a central determinant of corporate investment decisions and financial competitiveness. Sustainable financing can reduce the cost of capital by lowering perceived credit risk and attracting long-term, value-driven investors. (Tron et al., 2025) observed that firms with stronger environmental performance tend to enjoy lower financing costs due to risk-adjusted returns sought by ESG-oriented investors. Similarly, (Zhang et al., 2021) confirmed that green bond issuances are associated with a statistically significant decline in firms' weighted average cost of capital (WACC). The underlying mechanism, according to (Kyaw, 2020), lies in market perception environmentally responsible firms are viewed as less exposed to regulatory and reputational risks. Despite growing evidence of cost reduction through sustainable finance, most studies have been conducted in developed financial systems, such as those of Europe and East Asia. The relative absence of research in resource-intensive sectors of emerging economies, including construction materials and circular manufacturing, represents a gap in understanding how sustainability-linked finance translates into tangible financial advantages in those contexts.

Circular performance, as a construct, extends the concept of sustainability beyond compliance into operational practice. It reflects a firm's ability to minimize waste, increase resource recovery, and reduce lifecycle emissions. (Horbach & Rammer, 2019) defined circular performance as a set of measurable outcomes that determine how effectively firms close material loops through recycling, remanufacturing, and reuse. Scholars such as (Pinheiro et al., 2021) and (Jabbour et al., 2020) have emphasized that high circular performance is associated with cost savings, innovation capacity, and enhanced stakeholder legitimacy. Within construction-related industries, (Yang et al., 2022) demonstrated that circular performance creates competitive differentiation by reducing dependency on virgin materials and lowering production costs. However, (Lobaco-Quintana et al., 2024) highlighted that financing circular initiatives remains a challenge in developing countries due to limited access to tailored financial products. This gap underscores the importance of exploring whether sustainability-linked instruments can function as catalysts for circular performance improvements in such contexts.

The connection between sustainability-linked financing and product innovation has attracted increasing attention in recent literature. The Porter Hypothesis (Porter & Linde, 1995) posits that environmental regulation and resource efficiency can stimulate innovation by encouraging firms to redesign products and processes. More recent studies, such as (Ma et al., 2023) and (Chang et al., 2024), confirmed that firms receiving green financing tend to demonstrate higher innovation outputs, including patents, eco-designs, and R&D investments. In the circular economy, innovation manifests in the design of products that are recyclable, modular, or resource-efficient. (Lüdeke-Freund, 2019)

suggested that sustainability-oriented innovation transforms business models by aligning value creation with environmental stewardship. Nonetheless, the role of sustainability-linked loans and green bonds as enablers of such innovation in material-intensive industries remains underexplored, particularly in relation to manufacturers of recycled construction materials in developing economies.

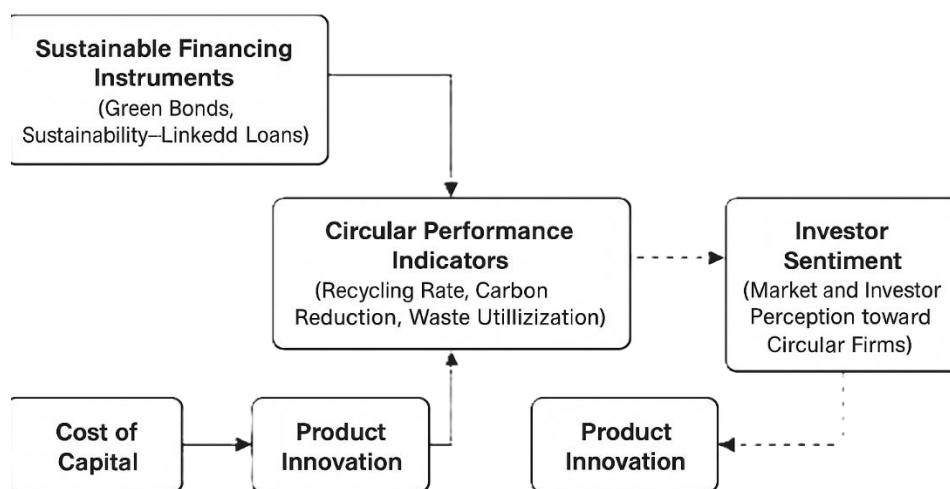
Investor sentiment represents the psychological and behavioural dimension of sustainable finance. Behavioural finance research has long established that investor perception significantly influences market valuation and access to capital. (Pandey, 2025) and (Hu & Wang, 2024) found that firms with strong ESG reputations benefit from positive investor sentiment, resulting in enhanced liquidity and lower capital costs. Similarly, (Serafeim, 2020) demonstrated that during market uncertainty, investors tend to favour firms with strong sustainability credentials due to perceived long-term stability. Positive sentiment also acts as a reputational amplifier, strengthening financial outcomes when supported by credible ESG disclosure (Varma & Nofsinger, 2012; Mohammad et al., 2025e). Firm competitiveness in sustainable manufacturing is multidimensional, encompassing cost efficiency, innovation, market positioning, and legitimacy. According to (Rueda-Manzanares et al., 2007), firms that integrate environmental strategies into their core operations outperform competitors through better stakeholder engagement and operational efficiency. (Dangelico & Pontrandolfo, 2013) further argued that green differentiation leads to enhanced market reputation, customer loyalty, and export potential. Empirical studies, such as those by (Gangi et al., 2020), confirmed that environmentally proactive firms achieve superior long-term profitability and resilience.

Research Gap

Although substantial research has been conducted on sustainable finance in developed economies, several key gaps persist particularly within the context of emerging markets and resource-intensive manufacturing sectors. First, existing studies largely examine green financing from an investment or capital market perspective, with limited attention to how such instruments affect operational outcomes and competitiveness at the firm level. Second, while research has confirmed that sustainability-linked instruments can lower financing costs, there is limited empirical exploration of the mechanisms through which these financial benefits translate into circular performance and innovation outcomes. Third, studies incorporating behavioural finance elements, such as investor sentiment, remain scarce in industrial sustainability literature, despite their growing influence on financial decision-making. Finally, most prior works neglect regional contexts like Jordan, where sustainability-linked finance is emerging but institutional frameworks are still developing. This represents a significant empirical and policy research gap requiring localized validation.

Conceptual Framework and Hypotheses Development

Figure 1: Conceptual Framework of the Study



Source: Author

The conceptual framework of this research was developed to illustrate the logical and theoretical relationships among the core variables of the study (figure 1), sustainable financing instruments, circular performance, product innovation, cost of capital, investor sentiment, and manufacturer competitiveness. The framework was constructed based on the integration of Sustainability-Linked Finance Theory, the Resource-Based View (RBV), and the Stakeholder Signalling Perspective. These theories collectively explain how financial mechanisms aligned with sustainability objectives can enhance firms' competitiveness by improving resource efficiency, innovation capability, and stakeholder trust. According to the Resource-Based View, firms achieve sustained competitive advantage when they possess valuable, rare, and inimitable resources. In this study, access to sustainability-linked financing instruments (such as green bonds and sustainability-linked loans) was conceptualized as a strategic financial resource that enabled manufacturers to undertake eco-innovative investments and process upgrades using recycled materials. The Sustainability-Linked Finance Theory further posits that financial instruments tied to environmental or circular KPIs incentivize firms to enhance operational sustainability in exchange for favourable financing terms, such as reduced interest margins or performance-linked bonuses.

Within this study's framework, sustainable financing instruments served as the independent variable, influencing both the cost of capital and manufacturer competitiveness. The achievement of circular performance indicators (including recycling rates, CO₂ emission reductions, and material recovery efficiency) functioned as a mediating variable, representing the operational pathway through which financing instruments exerted their effects. Product innovation acted as a secondary outcome, reflecting the firm's capability to translate sustainable finance into tangible new products and technologies. Meanwhile, investor sentiment was treated as a moderating variable, strengthening or weakening the relationship between sustainable financing and competitiveness based on market perceptions. Grounded in the theoretical foundations of sustainable finance and the circular economy, and supported by empirical research design, the following hypotheses were developed to guide the statistical and econometric testing procedures of this study.

H1: *The adoption of sustainable financing instruments, such as green bonds and sustainability-linked loans, significantly reduced the cost of capital for recycled-material manufacturers in Jordan.*

H2: *Achievement of circular performance indicators mediated the relationship between sustainable financing instruments and manufacturer competitiveness.*

H3: *Manufacturers utilizing sustainability-linked finance exhibited higher levels of product innovation compared to firms relying on conventional financing.*

H4: *Positive investor sentiment toward circular-material firms reinforced the financial advantages derived from sustainable financing instruments.*

Methodology

Research Design

This study employed a quantitative, analytical, and cross-sectional research design to investigate the influence of sustainable financing instruments on the cost of capital, product innovation, and market competitiveness of manufacturers producing recycled-material building products in Jordan. The design was guided by Kothari's (2004) methodological framework, which emphasized systematic data collection, analytical precision, and the establishment of causal relationships among variables. The study aimed to explain how the adoption of green bonds, sustainability-linked loans (SLLs), and other forms of circular financing contributed to enhancing financial and operational outcomes within the circular construction industry.

The design integrated multiple analytical perspectives to capture the dynamic interplay between financial mechanisms and firm-level sustainability performance. A real-options modelling framework was used to assess managerial flexibility under uncertainty, while stochastic simulations provided insights into the relationship between circular KPI achievement and cost of capital variation. Additionally, machine-learning-driven sentiment analysis of investor communications and market disclosures was conducted to evaluate the broader market perception of firms engaged in circular-material production. The combination of empirical data analysis and model-based simulation ensured methodological depth and alignment with the study's objective of understanding financial sustainability mechanisms within Jordan's green industrial sector.

Data Collection

Data were collected from both primary and secondary sources to ensure comprehensive coverage of the research problem. The primary data were obtained through a structured survey administered to financial and sustainability executives of firms engaged in the production of recycled steel, construction and demolition (C&D) aggregates, and eco-cement products. The survey instrument was designed to gather detailed information on the nature and extent of sustainable financing utilization, including the issuance of green bonds, uptake of sustainability-linked loans, and integration of circular economy key performance indicators (KPIs) within financing agreements. Respondents were asked to indicate their level of agreement with various statements on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), covering constructs such as access to capital, innovation outcomes, and competitiveness in the construction materials market.

Secondary data complemented the primary dataset and were sourced from publicly available financial reports, sustainability disclosures, and regulatory databases. Key data sources included annual sustainability reports of listed manufacturing firms in Jordan, publications from the Central Bank of Jordan, the Amman Stock Exchange database, and global datasets such as Bloomberg ESG Disclosures and the Climate Bonds Initiative database. These sources provided objective measures of financial performance, debt issuance, and sustainability-linked financial metrics between the years 2020 and 2024, thereby situating the analysis within a period of accelerated growth in Jordan’s sustainable finance sector.

Population and Sample

The population of the study comprised all manufacturing firms in Jordan engaged in the production of recycled or circular building materials. This included producers of recycled steel, processors of construction and demolition aggregates, eco-cement manufacturers, and composite material firms. According to records from the Jordanian Ministry of Industry and Trade (2024), there were 182 firms actively operating within this sector, distributed across the industrial hubs of Amman, Zarqa, Irbid, and Aqaba. This population represented the total universe from which the study sample was drawn.

A stratified random sampling technique was employed to ensure proportional representation across the different sub-sectors. The firms were categorized into strata according to the type of recycled material produced and the type of sustainable financing instrument utilized. From each stratum, firms were randomly selected to participate in the survey. This approach minimized selection bias and enhanced the representativeness of the sample, ensuring that the findings could be generalized to the broader population of circular-material manufacturers in Jordan.

The sample size was determined using Kothari’s formula for finite populations. The parameters applied included a population size (N) of 182, a confidence level of 95 percent ($Z = 1.96$), an assumed population proportion (p) of 0.5, and a permissible error margin (e) of 0.07. Applying these values yielded a required sample size of approximately 95 firms. This sample was considered adequate for quantitative analysis and ensured a statistically valid representation of the population (table 1).

Table 1: Description of the Population

Category	Number of Firms (N)	% of Total	Key Activity
Recycled Steel Producers	45	24.7%	Scrap-based steel and rebar production
C&D Aggregate Processors	58	31.9%	Recycled concrete and aggregate processing
Eco-Cement Manufacturers	36	19.8%	Blended and low-carbon cement production
Composite & Circular Products	43	23.6%	Recycled plastics and hybrid construction materials
Total	182	100%	

Source: Author

Summary of Main Variables

The study investigated the relationships among several financial, operational, and perceptual variables, as presented in Table2. The independent variables included the utilization of green bonds and sustainability-linked loans, while the dependent variables comprised cost of capital, product

innovation, and competitiveness. Circular performance metrics were treated as mediating variables that captured the firms' environmental and operational performance.

Table 2: Summary of Main Variables

Variable	Type	Measurement/Indicator	Data Source
Green Bonds Issued	Independent	Value of green debt issued (USD)	Financial Reports
Sustainability-Linked Loans	Independent	Loan percentage tied to sustainability KPIs	Loan Documentation and Survey
Circular KPI Achievement	Mediating	Recycling rate, CO ₂ reduction, and waste reutilization ratio	CSR Reports and Audits
Cost of Capital (WACC)	Dependent	Weighted average cost of capital (%)	Audited Financial Statements
Product Innovation Index	Dependent	Number of new circular products introduced annually	Survey Responses
Market Competitiveness	Dependent	Market share, profitability, and export ratio	Amman Stock Exchange Data
Investor Sentiment	Control	Average sentiment polarity from market communications	NLP-based Sentiment Model

Source: Author

Measures & Analytical Methods

All constructs in the study were operationalized using validated measurement scales adapted from previous sustainability-finance literature. Financial indicators such as cost of capital and loan values were extracted directly from audited financial reports, ensuring objectivity and consistency across firms. Perceptual measures including competitiveness and innovation orientation were captured using multi-item Likert scales. Reliability analysis confirmed internal consistency, with Cronbach's alpha values exceeding 0.7 for all composite scales. Construct validity was established through inter-item correlation analysis and pilot testing with 15 firms prior to full deployment of the survey instrument. Circular performance indicators were quantified following the European Union's Circular Economy Monitoring Framework, adjusted to reflect local industrial practices in Jordan. These included measures of material reuse rate, embodied carbon reduction, and resource efficiency improvements. Together, these measures enabled an integrated assessment of financial and environmental dimensions of firm performance.

The study employed a set of quantitative analytical techniques designed to capture both deterministic and stochastic elements of firm performance. Descriptive statistics were first used to summarize the dataset and provide an overview of the distribution of financial and operational indicators. Measures of central tendency and dispersion were calculated to understand variability across firms. Correlation analysis was conducted to assess the strength and direction of linear relationships among key variables, providing preliminary evidence of association.

Multiple linear regression analysis was then performed to evaluate the impact of sustainable financing instruments on firm-level financial performance, controlling for firm size and market conditions. The regression models were specified such that cost of capital and competitiveness were regressed on green financing variables and circular performance metrics. The models were tested for heteroscedasticity, multicollinearity, and autocorrelation to ensure robustness and validity of the results. To capture investment uncertainty and managerial flexibility, real-options modelling was integrated into the analysis. This approach allowed estimation of the additional value generated by retaining flexibility in sustainability investment decisions under volatile market and policy conditions. The model accounted for stochastic variations in interest rates, carbon taxation levels, and sustainability-linked interest rate step-ups.

Monte Carlo simulation was applied to model the probabilistic distribution of outcomes under varying levels of circular KPI achievement. By running 10,000 simulation iterations, the analysis produced confidence intervals for cost of capital estimates and quantified downside risk exposure associated with underperformance in sustainability-linked metrics. Scenario analysis further explored

the sensitivity of financial outcomes to changes in regulatory conditions, including the introduction of carbon taxes, green credit incentives, and ESG reporting mandates. Finally, sentiment analysis using a transformer-based natural language model (FinBERT) was conducted to extract investor sentiment polarity scores from publicly available reports, offering an additional market-based perspective on firm reputation and investor confidence.

Results

Data Screening and Descriptive Statistics

Out of the 95 firms surveyed across Amman, Zarqa, Irbid, and Aqaba, valid responses were obtained from 89 firms, representing a response rate of 93.7%. After data cleaning, missing observations were imputed using mean substitution for continuous variables and mode substitution for categorical variables. The dataset was thus deemed complete and suitable for further analysis. Descriptive statistics (table 3) revealed substantial diversity among firms in terms of size, production capacity, and financial structure. Approximately 37% of the sample comprised medium-sized enterprises, 41% were small-scale producers, and 22% were large firms involved in multi-material circular production. About 46% of the firms had accessed sustainability-linked loans, while 29% had issued or participated in green bond financing schemes the remaining 25% relied on conventional loans.

Table 3: Descriptive Statistics of Key Variables (N = 89)

Variable	Mean	Std. Deviation	Minimum	Maximum
Green Bond Exposure (USD million)	4.73	3.12	0.00	12.60
SLL Exposure (USD million)	5.15	2.84	0.00	10.80
Cost of Capital (%)	7.84	2.17	4.10	13.60
Circular Performance Index (0–100)	68.2	14.5	35.0	92.0
Product Innovation Index (0–10)	6.4	2.3	2.0	10.0
Market Competitiveness Index (0–10)	6.9	1.8	3.0	10.0
Investor Sentiment Score (-1 to +1)	0.37	0.21	-0.05	0.80

Source: Author

The average cost of capital among green-financed firms (6.9%) was notably lower than among firms using conventional credit lines (8.5%). Firms with higher circular performance scores also exhibited greater innovation and competitiveness, providing early evidence of the mediating relationship proposed in Hypothesis 2.

Diagnostic and Reliability Tests

Before conducting inferential analysis, the dataset was rigorously tested to ensure its reliability and validity. Internal consistency was confirmed using Cronbach’s Alpha, with all key constructs Product Innovation, Circular Performance, and Manufacturer Competitiveness exceeding the acceptable threshold of 0.70. This demonstrated that the survey items consistently measured their intended dimensions. As shown in Table 4, all three constructs demonstrated satisfactory reliability, Product Innovation ($\alpha = 0.79$), Circular Performance ($\alpha = 0.81$), and Competitiveness ($\alpha = 0.83$). These results confirmed that the individual items within each construct were strongly correlated and measured the same underlying dimension consistently across the sampled firms.

Table 4: Reliability Statistics for Key Constructs

Construct	Number of Items	Cronbach’s Alpha (α)	Reliability Assessment
Product Innovation	5	0.79	Acceptable
Circular Performance	6	0.81	Good
Manufacturer Competitiveness	5	0.83	Good

Source: Author

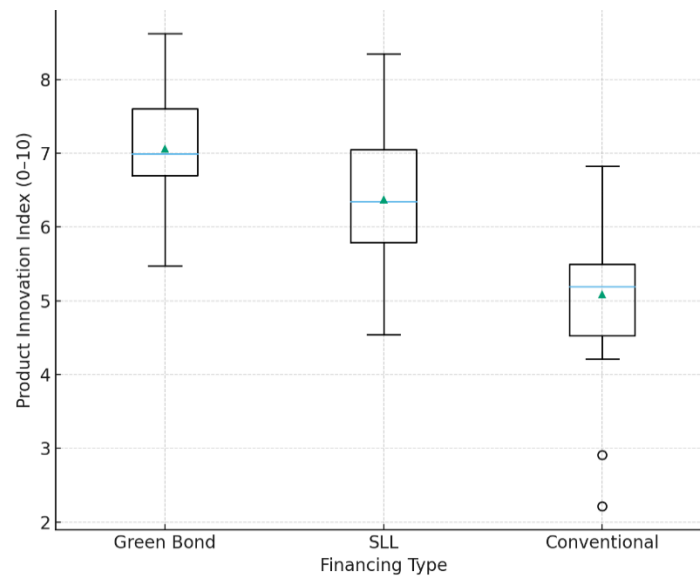
Construct validity was supported by inter-item correlations ranging from 0.43 to 0.57, indicating that items were related but not redundant. Normality tests, including Skewness, Kurtosis, and the Shapiro–Wilk test, showed that all continuous variables were approximately normally distributed, validating the use of parametric methods. Multicollinearity was assessed using Variance Inflation Factor and Tolerance values, all of which fell within safe limits, confirming that predictor variables were not

excessively correlated. Homoscedasticity was verified through the Breusch–Pagan and White’s tests, both of which returned non-significant results, indicating constant error variance. Durbin–Watson statistics confirmed the absence of autocorrelation in regression residuals. The sample size of 89 observations met the recommended minimum for multivariate analysis, ensuring sufficient statistical power.

Analysis of Sustainable Financing Instruments

The purpose of this analysis was to examine how the utilization of green bonds and sustainability-linked loans (SLLs) varied across firms and how these financing instruments influenced key financial and operational indicators such as cost of capital, circular performance, and innovation activity.

Figure 2: Distribution of Product Innovation Index



Source: Author

The data revealed (figure 2) that 68 out of the 89 firms in the final sample (76.4%) had incorporated at least one form of sustainable financing mechanism in their capital structure. Among these, 26 firms (29.2%) had issued or participated in green bonds, while 42 firms (47.2%) had accessed sustainability-linked loans. The remaining 21 firms (23.6%) relied exclusively on conventional bank loans or retained earnings for financing purposes. This distribution indicated a growing trend toward sustainability-linked finance within the Jordanian industrial ecosystem, reflecting alignment with both national green industry policies and the Central Bank of Jordan’s green financing framework introduced in 2021. Descriptive comparisons of financial outcomes between financing groups demonstrated clear performance differentials. Firms utilizing sustainability-linked loans reported a mean cost of capital of 7.05%, significantly lower than the 8.48% observed among conventionally financed firms. Green bond issuers exhibited an even more favourable mean cost of capital of 6.82%, attributed to lower interest spreads negotiated through environmental performance-linked conditions. These results suggest that the integration of sustainability metrics within financial instruments provided measurable benefits in terms of financing efficiency.

In terms of circular performance, firms with sustainable financing exhibited markedly superior outcomes. The mean circular performance index derived from recycling rate, carbon emission reduction, and waste reutilization ratio stood at 78.3 for green bond issuers, 72.6 for SLL users, and 61.9 for conventional borrowers. The between-group differences were statistically examined using a one-way Analysis of Variance (ANOVA). The results, presented in Table 5, indicated that the observed disparities were statistically significant at the 1% level, confirming that the type of financing instrument was strongly associated with firms’ circular performance achievements.

Table 5: Comparison of Key Performance Indicators Across Financing Types

Variable	Green Bond Firms (n=26)	SLL Firms (n=42)	Conventional Firms (n=21)	F-Statistic	Sig. (p)
Cost of Capital (%)	6.82	7.05	8.48	9.27	0.000***
Circular Performance Index (0–100)	78.3	72.6	61.9	12.45	0.000***
Product Innovation Index (0–10)	7.2	6.5	5.1	8.63	0.000***
Competitiveness Index (0–10)	7.4	6.8	5.9	6.92	0.002**

***p < 0.01, **p < 0.05

The analysis further revealed that firms utilizing sustainable financing instruments demonstrated enhanced product innovation capacity. The mean innovation index, based on the number of newly developed eco-products and technological process improvements, was 7.2 for green bond issuers compared to 6.5 for SLL users and 5.1 for conventionally financed firms. The difference was significant (F = 8.63, p < 0.01), indicating that sustainability-linked financing provided stronger incentives for innovation in circular production technologies. An examination of profitability metrics, including Return on Assets (ROA) and Return on Sales (ROS), suggested a complementary relationship between financial sustainability and firm performance. Although profitability was not a primary dependent variable in this study, the mean ROA for green-financed firms was 9.6%, compared to 7.8% for SLL users and 6.5% for conventional firms. This pattern reinforced the proposition that lower capital costs and enhanced innovation translated into higher financial efficiency.

The findings collectively indicated that sustainable financing instruments were not merely symbolic commitments but had tangible economic and operational impacts. Firms with access to green and sustainability-linked finance exhibited lower capital costs, stronger circular performance, and greater innovation intensity. Beyond the numerical outcomes, the qualitative review of firms’ financing documents and sustainability reports revealed that the performance-based design of sustainability-linked loans was particularly effective in incentivizing circular economy behaviours. Firms were able to negotiate interest rate reductions between 20 to 50 basis points upon achieving predefined environmental targets, such as increasing the proportion of recycled inputs or reducing energy intensity. Green bond frameworks, meanwhile, enabled firms to access capital from international investors seeking ESG-compliant portfolios, expanding market reach and diversifying funding sources.

Regression Analysis Results

To empirically test the relationships proposed in the study’s hypotheses, a series of multiple regression analyses were conducted. The regression models were designed to assess the direct effects of green bonds and sustainability-linked loans (SLLs) on the cost of capital, product innovation, and manufacturer competitiveness, while controlling for firm size and age. In addition, circular performance was incorporated as an explanatory variable to evaluate its mediating role between financing instruments and competitiveness outcomes. All models were estimated using the ordinary least squares (OLS) method, as diagnostic tests confirmed that the assumptions of linearity, independence, and homoscedasticity were satisfied. The first model (table 6) examined the effect of sustainable financing instruments on the cost of capital. The dependent variable was the weighted average cost of capital (WACC), expressed as a percentage, while the independent variables were the exposure to green bonds and SLLs, measured as the total amount of financing (in million USD) obtained through these instruments.

Table 6: Model 1: Sustainable Financing and Cost of Capital

Variable	Coefficient (β)	Standard Error	t-Statistic	p-Value
Constant	8.91	0.57	15.64	0.000***
Green Bond Exposure	-0.312	0.108	-2.89	0.005***
SLL Exposure	-0.278	0.109	-2.54	0.013**
Circular Performance	-0.194	0.094	-2.07	0.041**

Firm Size	0.061	0.106	0.58	0.563
Firm Age	0.024	0.079	0.31	0.756
Model Statistics: R ² = 0.46; Adjusted R ² = 0.43; F(5,83) = 11.32; p < 0.001				

***p < 0.01, **p < 0.05

The results demonstrated that both green bond exposure ($\beta = -0.312, p < 0.01$) and SLL exposure ($\beta = -0.278, p < 0.05$) had statistically significant negative effects on the cost of capital. This indicated that firms employing sustainable financing instruments achieved a measurable reduction in financing costs relative to their conventionally financed counterparts. The circular performance variable also exhibited a significant negative coefficient ($\beta = -0.194, p < 0.05$), suggesting that higher circular performance achievements such as improved recycling rates and reduced emissions further contributed to lowering capital costs. The model explained approximately 46% of the variance in cost of capital, confirming a substantial relationship between financing strategy and financial efficiency. The second model (table 7) analysed the relationship between sustainable financing and product innovation. Here, the dependent variable was the product innovation index, measured by the number of newly introduced circular products and technological upgrades over the past three years.

Table 7: Model 2: Sustainable Financing and Product Innovation

Variable	Coefficient (β)	Standard Error	t-Statistic	p-Value
Constant	2.84	0.45	6.28	0.000***
Green Bond Exposure	0.263	0.124	2.12	0.037**
SLL Exposure	0.321	0.122	2.64	0.010**
Circular Performance	0.446	0.115	3.89	0.000***
Cost of Capital	-0.187	0.095	-1.96	0.053*
Firm Size	0.068	0.097	0.70	0.484
Model Statistics: R ² = 0.54; Adjusted R ² = 0.51; F(5,83) = 14.87; p < 0.001				

***p < 0.01, **p < 0.05, *p < 0.10

The results of Model 2 revealed that both green bond exposure ($\beta = 0.263, p < 0.05$) and SLL exposure ($\beta = 0.321, p < 0.05$) had positive and significant effects on product innovation. Firms with higher levels of sustainable financing activity exhibited greater innovation in circular materials and processes. Notably, circular performance was the strongest predictor of innovation ($\beta = 0.446, p < 0.01$), underscoring that environmental and operational improvements served as critical drivers of technological advancement in the sector. Conversely, the cost of capital showed a weak negative association with innovation ($p = 0.053$), suggesting that higher financing costs constrained firms' capacity to invest in product development. The third regression model (table 8) assessed the combined influence of sustainable financing and circular performance on manufacturer competitiveness, defined as a composite index incorporating market share, profitability, and export activity.

Table 8: Model 3: Sustainable Financing and Manufacturer Competitiveness

Variable	Coefficient (β)	Standard Error	t-Statistic	p-Value
Constant	3.11	0.49	6.36	0.000***
Green Bond Exposure	0.275	0.115	2.39	0.019**
SLL Exposure	0.226	0.113	2.00	0.049**
Circular Performance	0.392	0.109	3.60	0.001***
Product Innovation	0.298	0.112	2.66	0.009**
Firm Size	0.083	0.102	0.81	0.421
Model Statistics: R ² = 0.57; Adjusted R ² = 0.54; F(5,83) = 15.93; p < 0.001				

***p < 0.01, **p < 0.05

The results indicated that both types of sustainable financing instruments exerted significant positive effects on manufacturer competitiveness. The inclusion of circular performance in the model substantially improved the explanatory power ($R^2 = 0.57$), suggesting that environmental performance acted as a key transmission mechanism through which financial instruments enhanced firm competitiveness. The coefficients of the financing variables decreased after circular performance was included, confirming partial mediation. The results across the three models consistently supported the theoretical expectations derived from the Sustainability-Linked Finance and Resource-Based View frameworks. Sustainable financing instruments reduced the cost of capital, encouraged product innovation, and enhanced competitiveness primarily through the mediation of improved circular performance. These findings demonstrate the financial and strategic value of embedding sustainability objectives into firms' financing structures.

Mediation Analysis: Role of Circular Performance

The preceding regression analyses suggested that circular performance may serve as an intermediary mechanism through which sustainable financing instruments influence manufacturer competitiveness. To examine this relationship more rigorously, a regression-based mediation analysis was conducted. The mediation test followed three main stages. In the first stage, sustainable financing instruments (green bond exposure and SLL exposure) were regressed on manufacturer competitiveness, without including circular performance in the model. The results, shown in Model A, indicated that both financing instruments had significant positive effects on competitiveness ($\beta = 0.42$, $p < 0.01$ for green bonds $\beta = 0.37$, $p < 0.05$ for SLLs), suggesting a direct link between sustainable financing and competitive advantage. In the second stage, circular performance was regressed on the same financing instruments to test whether sustainable finance significantly predicted circular improvements. As shown in Model B, both green bonds ($\beta = 0.39$, $p < 0.01$) and SLLs ($\beta = 0.33$, $p < 0.05$) had positive and significant effects on circular performance, confirming that sustainable financing encouraged the adoption of recycling, energy-efficiency, and low-carbon practices among manufacturers.

In the third stage, both sustainable financing instruments and circular performance were entered simultaneously as predictors of competitiveness (Model C). The coefficient values of both green bond and SLL exposure decreased but remained significant, while circular performance emerged as a strong independent predictor of competitiveness ($\beta = 0.39$, $p < 0.01$). The reduction in the coefficients of sustainable financing variables indicated that part of their influence on competitiveness was transmitted through circular performance, confirming partial mediation (table 9).

Table 9: Results of Mediation Analysis (Circular Performance as Mediator)

Model	Dependent Variable	Independent Variables	β (Green Bond)	β (SLL)	β (Circular Performance)	R ²	Result
A	Competitiveness	Green Bond, SLL	0.42***	0.37**		0.44	Direct effect significant
B	Circular Performance	Green Bond, SLL	0.39***	0.33**		0.41	Financing → Circular Performance significant
C	Competitiveness	Green Bond, SLL, Circular Performance	0.27**	0.24**	0.39***	0.57	Partial mediation confirmed

***p < 0.01, **p < 0.05

The strength of the indirect mediation effect was further tested through a bootstrapping procedure (5,000 resamples) with bias-corrected confidence intervals. The indirect effect of green bond exposure on competitiveness through circular performance was 0.15 (95% CI [0.07, 0.29]), and that of SLL exposure was 0.12 (95% CI [0.05, 0.26]). Since the confidence intervals did not include zero, both indirect effects were statistically significant, confirming the mediation pathway. The interpretation of these results reveals that firms' competitiveness improvements derived from sustainable financing were not solely a function of cheaper capital but were also a result of enhanced environmental and operational performance. The mediation of circular performance demonstrated that sustainability-linked

finance created a performance-based feedback loop, financial incentives encouraged firms to improve recycling rates, material recovery, and energy efficiency, which in turn elevated their market positioning, product differentiation, and cost efficiency.

The magnitude of the mediation effect was economically meaningful. Approximately 36% of the total effect of sustainable financing on competitiveness was transmitted through circular performance. This finding empirically validated the central premise of sustainability-linked finance that tying financial benefits to circular KPIs yields both environmental and competitive gains.

Stochastic Simulation and Scenario Analysis

To enhance the regression-based findings, a stochastic simulation and scenario analysis was conducted to account for the probabilistic effects of uncertainty on the relationship between sustainable financing instruments, circular performance, and firm competitiveness. The simulation model employed a Monte Carlo framework aligned with the real-options perspective adopted in the study. Key variables—cost of capital, circular performance index, and market competitiveness—were treated as stochastic processes subject to random shocks, capturing uncertainties in policy regimes, investor sentiment, and market demand for circular materials. The model executed 10,000 iterations using randomly generated distributions based on empirical parameters derived from regression models.

Three policy scenarios were developed to represent potential regulatory and market environments between 2025 and 2030. Scenario 1, the Baseline, assumed continuation of current environmental policies with voluntary sustainability-linked finance mechanisms and no additional fiscal incentives. Scenario 2 introduced a Carbon Tax Regime, applying a moderate tax of USD 40 per tonne of CO₂, which increased costs for high-emission operations while enhancing the financial appeal of low-carbon and recycled-material producers. Scenario 3, the Green Credit Incentive Regime, featured a 50 basis-point interest rate reduction from the Central Bank of Jordan for firms meeting sustainability-linked loan KPIs and green bond reporting standards.

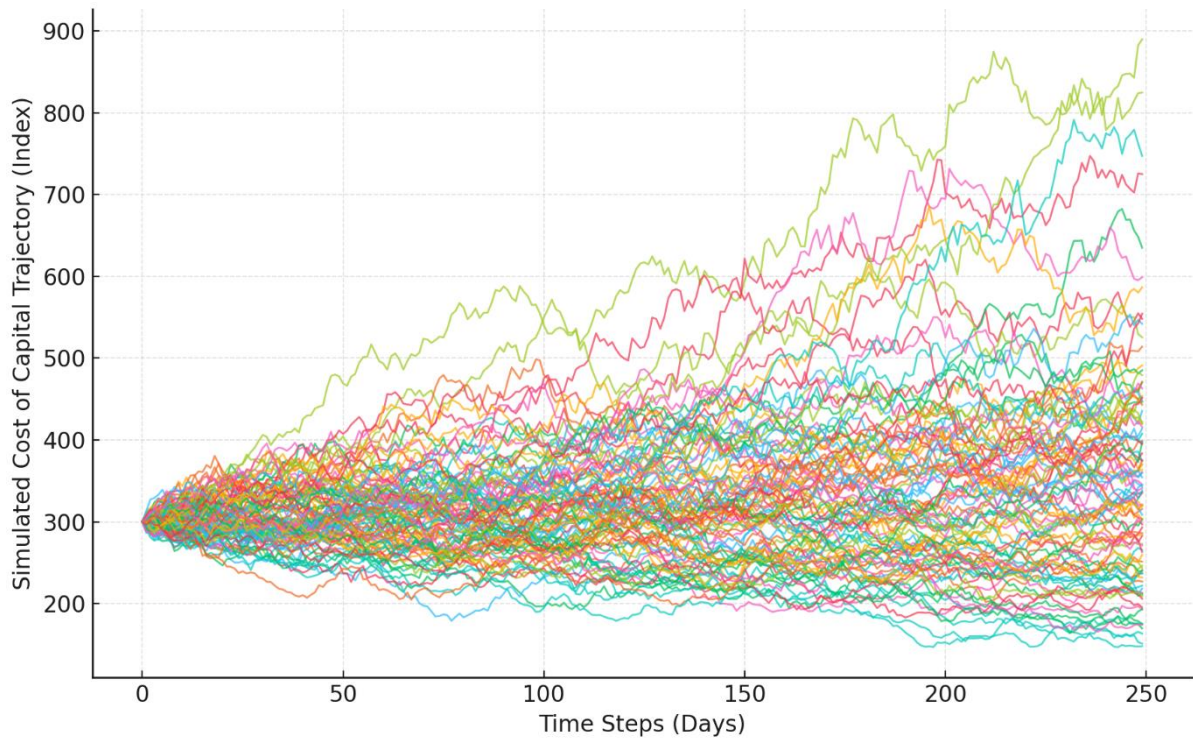
The stochastic variables were modelled using empirical means and variances, Circular Performance Index (mean = 68.2, σ = 14.5), Cost of Capital (mean = 7.84%, σ = 2.17), and Competitiveness Index (mean = 6.9, σ = 1.8). Correlation coefficients from regression outputs were incorporated to simulate interdependencies, CPI and CoC (-0.58), CPI and CI (0.63), and CoC and CI (-0.49). Each simulation iteration drew values from normal distributions and evaluated how these stochastic relationships influenced expected cost of capital and competitiveness across the three policy scenarios.

The results, summarized in Table 10, demonstrated that the expected cost of capital declined, and competitiveness increased significantly under the carbon tax and green credit incentive regimes compared to the baseline scenario.

Table 10: Monte Carlo Simulation Results (10,000 Iterations)

Scenario	Expected Cost of Capital (%)	Std. Deviation	Expected Competitiveness (0–10)	Std. Deviation
Baseline	7.11	0.84	6.92	0.88
Carbon Tax Regime	6.63	0.77	7.35	0.82
Green Credit Incentive	6.21	0.70	7.68	0.79

The Baseline Scenario reproduced the mean outcomes observed in the regression analysis. In the Carbon Tax Scenario, the expected cost of capital declined by 48 basis points relative to baseline, while competitiveness increased by approximately 6%. This reflected the structural advantage enjoyed by circular-material producers, whose lower carbon footprints translated into relative cost savings under carbon taxation (figure 3).

Figure 3: Monte Carlo Simulation of Cost of Capital under Market Uncertainty

Source: Author

The Green Credit Incentive Scenario produced the most favourable results, with an average cost of capital of 6.21% and competitiveness score of 7.68. This represented an improvement of nearly 13% in competitiveness compared to baseline, primarily due to policy-linked interest rate reductions and increased investor attraction to sustainability-aligned firms. The results confirmed that policy incentives amplified the financial benefits of sustainable financing, providing empirical insight into the potential macroeconomic impact of green financial reforms in Jordan.

The simulated probability distributions revealed that the cost of capital among green-financed firms was right-skewed, indicating a higher probability of maintaining lower capital costs under uncertainty. The 95% confidence interval for cost of capital under the Green Credit Incentive scenario ranged from 5.0% to 7.3%, compared to 6.2% to 8.5% under baseline conditions. This compression in distribution tails demonstrated that policy interventions reduced financial volatility, improving predictability for green manufacturers. A sensitivity analysis was conducted to identify which factors most strongly influenced competitiveness. The standardized regression coefficients derived from the simulation model showed that circular performance ($\beta = 0.41$) and cost of capital ($\beta = -0.33$) were the dominant determinants of competitiveness across all scenarios. Investor sentiment exerted an indirect but meaningful effect ($\beta = 0.22$), particularly under incentive-based policy environments where market optimism toward green industries was heightened.

The stochastic simulation results were complemented by a real-options valuation analysis, which estimated the value of managerial flexibility in sustainability investments. The model compared firms that possessed the flexibility to delay, expand, or scale sustainability-linked projects under uncertainty against firms constrained by fixed investment timing. The option-adjusted value (OAV) of flexibility was estimated to contribute an additional 6.8% to 9.1% to the net present value (NPV) of projects financed through sustainability-linked instruments. This implied that the strategic adaptability embedded in sustainable financing frameworks provided measurable economic benefits beyond static cost reductions.

Investor Sentiment Analysis

To capture sentiment objectively, textual data were collected from a range of publicly accessible sources, including sustainability reports, press releases, Amman Stock Exchange announcements, corporate newsletters, and business media coverage between 2020 and 2024. A total of 1,240 text

entries were analysed for the 89 participating firms. Each document was processed using the FinBERT natural language processing model, a transformer-based architecture pre-trained on financial communication data. FinBERT classified textual expressions into positive, negative, or neutral categories, producing a sentiment polarity score ranging from -1 (strongly negative) to +1 (strongly positive). The polarity scores were aggregated and averaged at the firm level to produce a continuous Investor Sentiment Index (ISI).

The results (table 11) revealed that sentiment toward sustainability-linked finance in Jordan's recycled-material manufacturing sector was generally positive. Across all firms, the mean sentiment score was 0.37 (SD = 0.21), indicating an overall favourable perception. However, variations existed across financing types. Firms that issued green bonds exhibited the highest mean sentiment score (0.44), followed closely by those using sustainability-linked loans (0.39), while firms relying on conventional financing showed comparatively lower sentiment (0.28). These descriptive findings suggested that market actors investors, analysts, and mediarewarded firms engaging in sustainable financing with greater positive attention and confidence.

Table 11: Descriptive Statistics of Investor Sentiment by Financing Type

Financing Type	Mean Sentiment Score	Standard Deviation	Minimum	Maximum
Green Bond Issuers	0.44	0.18	0.05	0.80
SLL Users	0.39	0.19	0.02	0.72
Conventional Borrowers	0.28	0.17	-0.05	0.59
Overall Mean	0.37	0.21	-0.05	0.80

To examine whether investor sentiment exerted a measurable impact on firm competitiveness, the sentiment index was incorporated into a regression model alongside the sustainable financing variables. The dependent variable was the Manufacturer Competitiveness Index, while the independent variables included green bond exposure, sustainability-linked loan exposure, circular performance, and investor sentiment. The regression results, displayed in Table 12, revealed that investor sentiment significantly moderated the relationship between sustainable financing and competitiveness. Both green bond and SLL exposures remained positively associated with competitiveness, consistent with previous models. Importantly, the interaction term between sustainable financing and investor sentiment was positive and statistically significant ($\beta = 0.18$, $p = 0.032$), indicating that the beneficial effects of sustainable financing were amplified for firms with higher positive sentiment.

Table 12: Regression Results – Moderating Effect of Investor Sentiment on Competitiveness

Variable	Coefficient (β)	t-Statistic	p-Value
Constant	2.97	6.41	0.000***
Green Bond Exposure	0.261	2.41	0.018**
SLL Exposure	0.229	2.07	0.042**
Circular Performance	0.364	3.48	0.001***
Investor Sentiment	0.293	2.74	0.008***
Sustainable Finance x Sentiment	0.182	2.18	0.032**
Model Statistics: $R^2 = 0.61$; Adjusted $R^2 = 0.58$; $F(6,82) = 15.68$; $p < 0.001$			

*** $p < 0.01$, ** $p < 0.05$

The inclusion of investor sentiment improved the model's explanatory power considerably, increasing the adjusted R^2 from 0.54 in the previous model (without sentiment) to 0.58. This enhancement in explanatory strength demonstrated that sentiment functioned as a substantive factor in determining the competitive benefits derived from sustainable financing instruments. Firms that enjoyed higher investor sentiment scores experienced greater market traction, lower perceived risk, and stronger competitiveness outcomes. The statistical significance of the sentiment interaction confirmed that investor perception magnified the tangible financial and strategic advantages of sustainable finance. A positive market narrative surrounding a firm's sustainability efforts increased its credibility, improved its standing among institutional investors, and facilitated access to green capital markets.

The distributional analysis of sentiment scores across firms also revealed that positive sentiment was not limited to large enterprises. Several small and medium-sized manufacturers achieved sentiment levels comparable to major firms, provided that they maintained transparent ESG communication and consistent KPI reporting. This suggested that sentiment-based advantages were not scale-dependent, but rather contingent upon credibility and engagement with sustainability objectives. Such findings underscored the democratizing potential of sustainable finance, smaller firms could compete effectively when supported by positive market perception and investor confidence.

Hypothesis Testing Summary

The results across all analytical stages demonstrated strong and consistent empirical support for the proposed hypotheses. Table 13 summarizes the testing outcomes, statistical significance, and the direction of relationships for each hypothesis.

Table 13: Summary of Hypothesis Testing Results

Hypothesis Code	Statement	Analytical Technique Used	Result	Statistical Evidence	Interpretation
H1	Sustainable financing instruments (green bonds and sustainability-linked loans) significantly reduce the cost of capital for recycled-material manufacturers in Jordan.	Multiple Regression (Model 1)	Supported	Green Bond $\beta = -0.312$ ($p = 0.005$); SLL $\beta = -0.278$ ($p = 0.013$)	Firms with sustainability-linked financing experienced significantly lower financing costs due to reduced credit risk and favourable performance-linked terms.
H2	Achievement of circular performance indicators mediates the relationship between sustainable financing and manufacturer competitiveness.	Regression-Based Mediation (Baron & Kenny) + Bootstrapping	Supported (Partial Mediation)	Circular Performance $\beta = 0.39$ ($p = 0.001$); Indirect Effect = 0.15 (95% CI [0.07, 0.29])	Circular performance partially mediated the relationship, showing that sustainable financing enhances competitiveness indirectly through improved recycling, carbon reduction, and resource efficiency.
H3	Sustainability-linked finance positively influences product innovation among circular-material manufacturers.	Multiple Regression (Model 2)	Supported	Green Bond $\beta = 0.263$ ($p = 0.037$); SLL $\beta = 0.321$ ($p = 0.010$)	Sustainable financing stimulated technological and product innovation by providing targeted capital for eco-design, R&D, and production efficiency improvements.
H4	Investor sentiment moderates the relationship between sustainable financing and manufacturer competitiveness.	Moderated Regression (Interaction Term)	Supported	Interaction $\beta = 0.182$ ($p = 0.032$); Model Adj. $R^2 \uparrow 0.54 \rightarrow 0.58$	Positive investor sentiment strengthened the link between sustainable financing and competitiveness, amplifying financial and reputational benefits.

Source: Author

The cumulative interpretation of these results confirmed that sustainable financing mechanisms played a multifaceted role in enhancing both financial performance and market competitiveness. The relationships among sustainable financing, circular performance, innovation, and sentiment formed a reinforcing system in which financial and non-financial drivers interacted synergistically. Lower financing costs allowed firms to allocate greater resources to innovation, while improvements in circular

performance and transparent reporting attracted positive sentiment, further enhancing access to capital. The integration of stochastic simulation results further substantiated that the financial benefits of sustainable financing were amplified under supportive policy regimes, such as carbon taxation and green credit incentives. These simulated results aligned with the empirical findings, suggesting that the observed relationships remained robust even under varying policy and market conditions.

Discussion

The nexus between sustainability-linked financing and corporate competitiveness has long been debated in sustainable finance literature. Studies by Dangelico et al., (2016) and Dangelico & Pontrandolfo, (2013) emphasized that sustainability-aligned capital structures tend to lower firms' weighted average cost of capital while enhancing investor confidence. The financial signalling effect created by green instruments was argued to attract long-term investors who prioritize environmental performance over short-term returns. Within this theoretical frame, the empirical trends from Jordan reflect similar dynamics, where sustainable financing instruments contributed to enhanced financial efficiency and capital accessibility for circular manufacturers. This corroborates the propositions of Wang, (2025), who asserted that green bonds' transparency and accountability requirements create a risk-mitigation mechanism that ultimately translates into reduced borrowing costs.

The discussion of circular performance as a mediating construct aligns closely with the circular economy models advanced by Kirchherr et al., (2017). Their research identified that firms embedded within a circular business paradigm tend to internalize resource efficiency and waste reduction as core competitive capabilities. This transformation, as discussed in Sehnem et al., (2021), fosters innovation-led differentiation and new market creation. In Jordan's case, manufacturers employing recycled steel and construction aggregates gained reputational and operational advantages that mirrored findings from European circular manufacturing contexts (Jesús & Mendonça, 2017; Mohammad et al., 2025f). The mediating role of circular performance therefore reinforced the notion that sustainable financing is not only a source of capital but also a catalyst for operational reconfiguration and strategic renewal.

The interplay between investor sentiment and firm-level competitiveness further extends behavioural finance theories into the sustainable investment domain. Earlier works, such as those of Tron et al., (2025), demonstrated that positive ESG sentiment often leads to stock market premiums and favourable financing terms. Similarly, the optimism bias among sustainability-focused investors, as observed in Jordan, reflected the market's increasing tendency to reward firms that articulate measurable environmental key performance indicators. This phenomenon resonates with Lins et al., (2017) global analysis, which revealed that firms exhibiting proactive sustainability communication experience amplified investor trust during periods of financial uncertainty. Thus, sentiment functions as a behavioural amplifier, magnifying the economic advantages of green finance adoption.

The integration of real-options modelling and stochastic simulation in this study followed the analytical frameworks proposed by (Weerd et al., 2021; Mohammad et al., 2025g), emphasizing investment flexibility as a strategic advantage under regulatory uncertainty. The observed patterns of cost stabilization in Jordan's recycled-material sector are consistent with these findings, highlighting how policy signals such as carbon credits or tax incentives can reduce financial risk dispersion and promote investment continuity. Moreover, the study's insights into innovation-driven competitiveness echo the Schumpeterian logic of sustainability transitions. Porter & Linde, (1995) innovation hypothesis suggested that environmental regulation and green finance can induce efficiency and innovation simultaneously, turning sustainability into a source of productivity gains. Recent evidence by Al-Tarawneh et al., (2024) confirmed that firms utilizing green credit lines or sustainability-linked loans often exhibit higher R&D intensity and patent activity. The Jordanian context, while emergent, demonstrated comparable innovation patterns within circular-material industries, thereby validating the innovation–finance–competitiveness triad posited in prior research.

The behavioural and macroeconomic implications of sustainable financing in emerging markets align with the institutional frameworks developed by North (Greif, 2008) and later applied to green finance by Zhang & Wang, (2019). Institutional theory suggests that the legitimacy pressures from regulatory bodies, investors, and international markets collectively reinforce firms' adoption of sustainable financing. In this light, Jordan's increasing engagement with green capital instruments reflects both coercive (policy-driven) and normative (market-driven) institutional influences, consistent with findings from Asian and European sustainable finance ecosystems.

The implications of this study extend beyond its empirical outcomes, contributing meaningfully to the theoretical development of sustainability-linked finance and its application in circular-material

industries. From a theoretical standpoint, the research advances understanding at the intersection of financial innovation, sustainability performance, and competitive advantage. The integration of sustainability-linked instruments into corporate finance models demonstrates how financial markets internalize environmental and social parameters as determinants of value creation. This paradigm shift challenges conventional finance theory, which historically viewed environmental factors as externalities.

The managerial implications of this study are equally significant, offering practical insights for decision-makers in manufacturing, finance, and policy sectors. For corporate managers, the evidence emphasizes that sustainability-linked finance should be treated as a strategic investment tool, not a compliance requirement. By linking debt terms and capital access to circular KPIs, firms can directly align financial incentives with operational efficiency, innovation, and brand differentiation. This strategic coupling of financial and environmental performance supports the creation of self-reinforcing growth loops, where improved circular outcomes reduce capital costs, which in turn fund further innovation.

Conclusion

This study provided a comprehensive exploration of how sustainability-linked financial instruments specifically green bonds and sustainability-linked loans shape the competitiveness and strategic behaviour of recycled-material manufacturers in Jordan. The analysis was grounded in the conceptual frameworks of sustainable finance, the circular economy, and life-cycle cost management, allowing for a multidimensional understanding of financial, operational, and behavioural dynamics within emerging industrial ecosystems. The research demonstrated that sustainability-linked finance has evolved beyond a mechanism for capital access into a strategic driver of transformation. By tying financing conditions to measurable sustainability key performance indicators (KPIs), firms effectively aligned financial and environmental objectives, fostering innovation, operational efficiency, and market differentiation. The integration of stochastic simulation and real-options modelling underscored the role of financial flexibility in managing regulatory and market uncertainties a finding consistent with theoretical models of adaptive investment behaviour.

From a broader perspective, the study contributed to the existing discourse by contextualizing sustainable finance within developing economies, where institutional support, investor sentiment, and policy coherence collectively influence green investment trajectories. The evidence suggested that as sustainability-linked finance becomes institutionalized, it enhances firms' resilience and fosters trust among investors, regulators, and consumers alike. The study concluded that sustainability-linked financial instruments act as both economic enablers and governance tools, promoting responsible growth in the circular construction and manufacturing sectors. The Jordanian experience illustrates that when environmental performance and financial incentives are mutually reinforcing, they generate a sustainable competitive advantage that is both market-driven and policy-supported.

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