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Linking financial technology, innovation, and green finance to drive sustainable performance of SMEs of Pakistan

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Abstract: Sustainability has become a strategic imperative for manufacturing SMEs amid increasing environmental regulations and stakeholder expectations. However, existing research offers limited insights into how digital financial innovations, particularly FinTech, contribute to sustainability performance in resource-constrained SMEs contexts. Addressing this gap, the present study investigates the impact of FinTech adoption (FA) on the sustainability performance (SP) of manufacturing SMEs, while exploring the mediating roles of organisational innovation (OI) and green finance (GF). Grounded in the resource-based view (RBV), the study develops a conceptual framework linking digital capabilities with sustainable outcomes. A quantitative research design was employed, and survey data were collected from 340 manufacturing SMEs in Pakistan. Structural equation modelling (SEM) was used to test hypothesised relationships. The results demonstrate that FA significantly improves sustainable performance both directly and indirectly through OI and GF. Furthermore, FA also mediates the relationship between GF and SP, emphasising its role in operationalising sustainable financial flows. This study provides empirical evidence that FA, when strategically integrated with innovation and financial mechanisms, acts as a transformative enabler of sustainability in SMEs. It contributes to theory by extending the RBV to include digital and green financial resources as dynamic capabilities for achieving environmental goals.

Keywords: financial technology; innovation; green finance; sustainable performance; Pakistan; resource-based view; RBV; structural equation modelling; SEM.

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1 Introduction

Increasing institutional pressures and evolving environmental regulations have made sustainability a strategic priority, with small and medium-sized enterprises (SMEs) playing a critical role in the global economic system. Their adoption of sustainability principles has gained notable attention from both scholars and policymakers (Gani et al., 2022). In many countries, governments are implementing stricter environmental regulations to reduce the negative ecological consequences of industrial and manufacturing activities (Joo and Min, 2023). This regulatory tightening has compelled firms to adopt sustainable production practices (Huang and Badurdeen, 2017). As a result, maintaining ecological integrity and upholding social responsibility have become pressing concerns for stakeholders. These concerns are central to achieving long-term sustainable development within the SME sector (Sheergojri et al., 2025). SMEs contribute significantly to environmental degradation, largely due to their high numbers and wide-ranging activities. Research indicates that SMEs are responsible for nearly 70% of global industrial waste pollution (Caldera et al., 2019). Therefore, incorporating sustainability into SMEs' operations is essential, not only for regulatory compliance but also to reduce their environmental footprint (Afolabi et al., 2023). The rise in environmental awareness among consumers has increased pressure on firms to adopt green practices. This shift in market preferences reflects a growing demand for environmentally friendly products and services (Rahman, 2021).

Nevertheless, SMEs, particularly those operating in manufacturing, continue to face challenges such as operational inefficiencies, which hinder their progress toward sustainable business practices (Jamwal et al., 2025; Satar and Alarifi, 2024). The literature highlights several barriers that obstruct the integration of sustainability within SMEs (Kumar et al., 2023). These include constrained financial resources, the high costs associated with sustainable technologies, and a lack of expertise or training in

environmental management (Gupta et al., 2020; Jesus et al., 2023). Furthermore, there remains a lack of consensus regarding the factors that significantly influence firms' sustainability performance (SP) (Pizzi et al., 2021a, 2021b; Rodríguez-Espíndola et al., 2022). In response, increasing scholarly attention has been directed toward the role of technological innovation, particularly Industry 4.0 technologies, in addressing these challenges. These technologies have been credited with enhancing efficiency, reducing waste, and supporting sustainable resource use (Ali et al., 2022).

Building on this foundation, the present study proposes that financial technology (FinTech), a prominent aspect of 4.0, may serve as a vital enabler of sustainability within SMEs. FinTech refers to using innovative technologies to enhance the efficiency and accessibility of financial services. The sector has been recognised for its disruptive capacity and rapid growth trajectory (Liu et al., 2021; Najaf et al., 2022; Jhunjhunwala and Chaudhuri, 2021). Although still emerging, increased investment in FinTech indicates growing confidence among institutional actors (Chen et al., 2021). FinTech applications often integrate advanced technologies such as machine-to-machine communication and the internet of things (IoT) to enhance transparency and efficiency in financial services (Huynh et al., 2020; Pizzi et al., 2021a, 2021b). Despite its transformative potential, the impact of FinTech adoption (FA) on SMEs sustainability remains underexplored. Existing research primarily focuses on financial performance, access to credit, and renewable energy (Croutzet and Dabbous, 2021; Abbasi et al., 2021; Anshari et al., 2019). However, empirical studies linking FA to sustainability outcomes are scarce (Liu et al., 2024; Pizzi et al., 2021a, 2021b; Vergara and Agudo, 2021). This study addresses this gap by examining how organisational innovation (OI) and green finance (GF) mediate the relationship between FA and SP in SMEs. It contributes to a deeper understanding of FinTech's role in advancing sustainable business models.

Building upon the premise that FA enhances firm capabilities, recent literature suggests that its influence on SP may operate through intermediate organisational mechanisms. Among these, OI and GF are emerging as significant enablers that can bridge the gap between technology adoption and sustainable outcomes (Elfaki and Ahmed, 2024). OI enables firms to develop new processes, redesign products, and restructure operations, all of which are crucial for meeting sustainability goals in a dynamic business environment (Fan et al., 2023). FinTech tools, such as blockchain, smart contracts, and real-time data analytics, can support such Innovation by improving decision-making, enhancing transparency, and fostering agility in operations (Pizzi et al., 2021a, 2021b).

Earlier literature suggests that GKS helps enhance the organisation towards a positive correlation between GSCM and environmental sustainability (Junejo et al., 2025). GF serves as a key mediator, setting up the necessary financial means for environmentally friendly investments and projects. Organisations can reduce costs, open more lending opportunities, and conduct digital audits through FinTech platforms. They can also obtain financing instruments such as green bonds and sustainability-linked loans to protect the environment (Jaiwant and Kureethara, 2023). Introducing digital financial technologies into business operations helps firms to access environmentally responsible financing to continue reinforcing their performance related to sustainability (Yang and Hui, 2024).

Strategic linkages between digital transformation and environmental goals are revealed through the mediating role of OI and GF, which contribute to explaining the analysed models. Based on the research gaps identified in prior literature, this study has some research objectives. This study aims to check the impact of FA on the SP of

manufacturing SMEs in Pakistan. It also examines whether OI and GF mediate the relationship between FA and SP. Further research assesses whether FA itself acts as a mediator between GF and SP.

This study draws upon the resource-based view (RBV) to argue that OI and GF represent critical strategic resources that enable firms to leverage FinTech capabilities for sustainable competitive advantage. FA may enhance operational efficiency; however, when complemented by OI and strategic financial resources like GF, it contributes more significantly to sustainability outcomes. Hence, the mediating role of these constructs is essential to understanding how FA translates into long-term SP within the SME sector.

The study addresses the following research questions:

- To what extent does FA influence the SP of manufacturing SMEs?
- Does OI mediate the relationship between FA and SP?
- Does GF mediate the relationship between FA and SP?
- How does FA mediate the relationship between GF and SP?

This study contributes to the growing discourse on sustainability and digital transformation in three significant ways. First, it enriches the FinTech literature by focusing on its implications beyond financial performance, specifically examining how FA can impact the SP of manufacturing SMEs in a context that remains underexplored. Second, by incorporating OI and GF as mediators, the study addresses the call for more complex, multi-dimensional models that capture the indirect pathways through which digital technologies affect sustainability outcomes (Yan et al., 2022). The study offers theoretical advancement by integrating the RBV to explain how internal capabilities (OI) and external strategic resources (GF) mediate the relationship between technology adoption and sustainability. This integrated framework provides a more holistic view of firm-level sustainability, demonstrating that digital adoption alone is insufficient without the supporting organisational and financial infrastructure. The findings are expected to guide SME managers, policy designers, and financial institutions in promoting synergistic strategies that combine FinTech tools with innovation capacity and access to GF.

2 Theoretical foundation

The RBV of the firm provides a robust theoretical framework for understanding how internal resources and capabilities contribute to sustainable competitive advantage and long-term performance. RBV proposed by Barney (1991) argues that firms achieve superior outcomes by developing and leveraging resources that are valuable, rare, inimitable, and non-substitutable (VRIN). FA can be conceptualised as a strategic resource that enhances operational flexibility, data integration, and access to financial mechanisms, core elements that modern firms require to survive and thrive in turbulent environments (Soni et al., 2022). However, the RBV emphasises that it is not the possession of resources alone, but their integration and deployment into organisational processes, that creates competitive advantage (Hitt et al., 2021). FinTech solutions such as blockchain, AI-based credit scoring and cloud-based financial planning systems provide firms, especially SMEs, with new avenues for transforming their financial

architecture. These technologies, when effectively embedded into the firm's strategic framework, can stimulate OI by enabling experimentation, real-time decision-making, and the development of new business models (Teece, 2007; Zahra and George, 2002). Innovation represents a dynamic capability that allows firms to reconfigure existing resources and remain aligned with shifting environmental demands (Eisenhardt and Martin, 2000). GF refers to a firm's strategic use of environmentally targeted financial instruments (Makhdoom et al., 2024). The RBV recognises financial capital as a foundational resource, but its strategic value increases when directed towards sustainable initiatives (Hart, 1995; Russo and Fouts, 1997). Green procurement methods are considered important in Pakistan's logistics. Green bonds, sustainability-linked loans, and ESG-focused investment channels are no longer peripheral; they form part of a firm's ability to align financial decision-making with environmental and social goals (Siegrist et al., 2020). Through FinTech-enabled mechanisms, SMEs can overcome traditional barriers to such capital, including information asymmetries and high transactional costs (Wang et al., 2022).

This composite strategic capability is achieved through the combination of FinTech's digital backbone and the use of Innovation as an evolving internal process and sustainability-driven funding sources called GF (Dangelico et al., 2017). The grade at which an organisation incorporates its assets into strategy measures that satisfy the stakeholder needs, as well as addressing both the regulatory demands and market needs, becomes the SP outcome of the firm. Environmental and social performance has shifted to emphasise external achievements over results of capability development (Zhang et al., 2023). Given that manufacturing companies usually face resource limitations but must be relatively flexible to redesign digital and financial instruments in the form of Innovation, this theoretical framing is close to manufacturers' SMEs (Ahmed et al., 2022). Drawing from the RBV theory, the proposed framework conceptualises FA as a strategic resource that directly enhances sustainable performance (SP) and indirectly influences it through two mediators: OI and GF. FA is posited to mediate the relationship between GF and SP, reflecting its enabling role in channelling environmentally oriented financial resources toward tangible sustainability outcomes. This configuration integrates technological, organisational, and financial capabilities into a unified model, addressing calls in the literature for multi-dimensional frameworks that capture the complex pathways through which digital transformation fosters sustainability (Pizzi et al., 2021a, 2021b). The model's novelty lies in situating FA at the intersection of internal innovation processes and external green financing mechanisms, thereby offering a more comprehensive understanding of how SMEs in resource-constrained environments can leverage digital tools to achieve long-term environmental, social, and economic goals.

2.1 Hypotheses development

2.1.1 FA and sustainable performance

Utilising digital connectivity to enhance productivity (including organisational performance) in various activities catalyses sustainable transformation across industries (Nobanee et al., 2019). Leong and Sung (2018) define FinTech as technology innovation used in financial service processes that could influence new business models. Based in Industry 4.0, FinTech is built on solutions for automation, big data analytics, blockchain,

and digital platforms aiming at solving the modern financial challenge and contributing to the resilience of small and medium enterprises (SMEs) (Khan et al., 2023).

FinTech tools help make financial operations more efficient by improving the way one makes financial decisions and also increase both the accessibility of capital for businesses and individuals (Shukla and Dubey, 2022). An example is provision of alternative financing channels to SMEs through Peer to Peer (P2P) lending, which serves as an alternative to conventional banking channels (Rabbani et al., 2023). This model helps support inclusive financial ecosystems; it helps to fund social and environmental initiatives (Ismail et al., 2022). FinTech facilitates proximate funding means like crowdfunding and microlending to boost capital accessible to resource-deprived enterprises to finance sustainable projects (Shaikh, 2021; Hidayat-ur-Rehman and Hossain, 2024).

Contemporary literature acknowledges the nexus between FinTech and environmental sustainability. Digital finance promotes the adoption of renewable energy technologies and energy-efficiency systems by eliminating operational inefficiencies through automation and data-driven optimisation (Chen et al., 2021). FinTech's capabilities enable sustainable investing choices and ecological resource management (Deng et al., 2019; Croutzet and Dabbous, 2021). In addition to its environmental influence, FinTech affects firms' consumption, savings, and investment behaviours (Che Hassan et al., 2024). It serves as the driver of environmental responsibility through promoting investments in green technology, reducing carbon footprints, and promoting resource efficiency (Muganyi et al., 2021). For this reason, FinTech is a strategic tool for incorporating sustainability into the functioning of a firm (Udeagha and Muchapondwa, 2023). As digital platforms have increased transparency and accountability of companies to execute their corporate social responsibility (CSR) practices, firms establish a more synergic line with stakeholder expectations (Liu et al., 2021). Industry 4.0 technologies enable organisations to implement socially responsible practices to promote societal well-being and develop long-term stakeholder trust (Tasleem et al., 2019). FinTech also facilitates green Innovation by supporting the effective development of sustainable products as well as the efficient operations of the supply chain. According to Guang-Wen and Siddik (2023), FinTech access to the GF aids people in achieving eco-innovation efforts, and these contributions are consistent with the practice-based view of the firm, whereby superior environmental and financial outcomes flow from the nature of the embedded firm practices. Thus, we hypothesise that:

H1 FA has a significant impact on sustainable performance.

2.1.2 Organisation innovation as a mediator

With rapid progress in the field of digital technology, adaptation and early adoption of FinTech has become a must for organisations nowadays to take strategic advantage of the advancements in financial processes; increase operational agility and service personalisation (George, 2024). Firms integrate digital technologies such as blockchain, artificial intelligence, and mobile payment systems to improve transactional efficiencies and customer responsiveness (Hopalı et al., 2022; Darwish, 2023). While these technological improvements are useful, it is important to optimally integrate them into the internal capacity to deliver more comprehensive performance objectives. In such a context, sustainable performance in terms of ecological responsibility, long-term

economic resilience, and social accountability is predicated on a complementary set of capabilities beyond mere technology deployment only (George and Schillebeeckx, 2022).

Technological capabilities are institutionalised, reconfigured, and directed toward sustainability objectives within an organisation by OI, which is an essential mechanism (Li et al., 2024). This involves developing new managerial practices, decision-making structures, and interdepartmental collaborations which enable firms to absorb and integrate succeeding technological advancements (Han et al., 2024). FinTech solutions are embedded through OI in the core routines to enhance governance, transparency, and resource efficiency, which are essential for sustainable performance (Rasheed et al., 2025). According to the dynamic capability's perspective, organisations need to repeatedly transform their structures and processes in line with technological opportunities, with Innovation creating the link between the digital developments on the outside and the sustainability outcomes on the inside (Vărzaru and Bocean, 2024; Teece, 2007).

Empirical studies show that those firms that strategically enhance OI have better performance with digital investments in terms of their sustainability outcomes (Gaosegelwe and Monametsi, 2024; Quttainah and Ayadi, 2024). For instance, research from the financial services and manufacturing industries suggests that internal innovative practices have a mediating effect on digital finance tools on environmental, social, and governance (ESG) metrics (Raihan and Uddin, 2023; Hopalı et al., 2022). The OI helps to adapt the digital financial technologies to the practices of sustainability-oriented strategies through business model shifting, deepening the engagement and value creation of the stakeholders and supply chain optimisation (Ermini et al., 2024). Thus, based on the above discussion, we hypothesised that;

H2 The impact of FA on sustainable performance mediated by OI.

2.1.3 GF as mediator

FinTech has transformed how capital is mobilised and allocated into financial systems, based on which goals are aligned with environmental sustainability (Carè et al., 2023). New tools that are available in the space of FinTech platforms, peer-to-peer lending, blockchain-based green bonds, and AI-driven risk assessment concerning environmentally sustainable projects are being provided (Santos and Carvalho, 2025). Digitalisation decreases transaction costs and increases financial inclusiveness, thereby overcoming informational asymmetries or high-risk profiles and opening green financial instruments to reach firms and projects that might be excluded by conventional finance (Liu et al., 2021). Yet, this materialises, in practice, only when these digital tools are channelled into mechanisms explicitly dedicated to funding or incentivising environmentally responsible behaviour.

Adoption of FinTech, in turn, channels the influence of GF on sustainable performance, which includes investment and lending practices that focus on those who consider environmental criteria in their activities (Carè et al., 2023). The data processing capacity and real-time analytics of FinTech make such an assessment possible, as well as monitoring of sustainability metrics and verification of the environmental integrity of funded projects (Dunbar et al., 2024). These capabilities enable the development of digital green financial services that not only support eco-innovation but also help a firm become a legitimate and competitive firm in markets where environmental concerns are

becoming prevalent (Quttainah and Ayadi, 2024). Therefore, it is practical and scalable for GF to use FinTech solutions in deployment.

This interconnected logic has recent empirical backing. It has been revealed that FinTech-based innovations of green loans, carbon credit platforms, and ESG data analytics help firms to achieve greater environmental performance if incorporated into a broader sustainability strategy (Quttainah and Ayadi, 2024). In addition to providing the means to access capital to sustainable projects, GF communicates environmental commitments to external stakeholders, which leads to the acquisition and appreciation of reputational capital and firm value (Wang, 2024; Carè et al., 2023). FinTech and GF weave together across borders to allow firms to incorporate sustainability into the financial decision processes as a way to decrease ecological footprints and increase long-term sustainability. Thus, we hypothesised that:

H3 The impact of FA on sustainable performance mediated by GF.

2.1.4 FA mediates

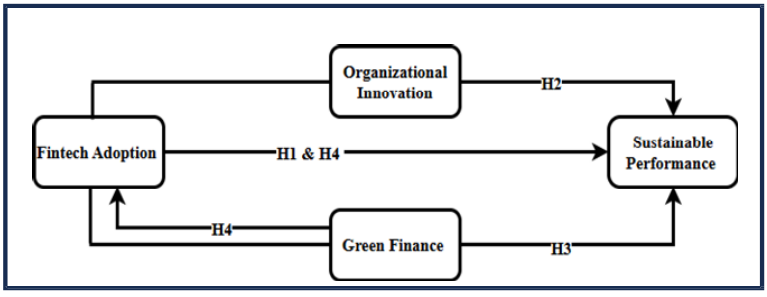
GF is essential in boosting the transition to sustainable economies by allocating financial resources toward environmentally responsible investments, green energy technologies, and carbon-neutral infrastructure (Qing et al., 2024). While money alone cannot unlock the potential of GF to drive impacts on the ground, there is a need for a sound mechanism that enforces implementation, monitoring, and evaluation of the capital that has been flowed. The FA plays a critical enabler in this context. FinTech integrates digital technologies, (e.g., blockchain, artificial intelligence, and big data analytics) to enable transparent, precise, and accessible green financial flows (Chaklader et al., 2023). These technologies provide a means of prediction and verification of green investment performance outcomes in real-time (Chen et al., 2021).

The role of FinTech in realising GF goals to be achieved in practice, and be traceable. If GF is not complemented by technological infrastructure, there exist inefficiencies, opacity, and limited reach (Zhang et al., 2022) that prevent it from delivering measurably sustainable outcomes. In this regard, FinTech covers this gap through the improvement of capital deployment efficiency, disclosure of ESG by enhancing disclosure requirements, and enabling the inclusion of smaller firms and underserved sectors in the ecosystem (Qing et al., 2024). Digital platforms can help green loan assessments, carbon footprint analysis automation, and smart contracts to ensure that funds are directed only to sustainable projects (Ghosh and Vinod, 2017). FinTech develops green financial inputs into strategic outcomes executed in the organisational practice of being aligned with the company's long-term sustainability goals (Yuan, 2025; Zhou et al., 2023).

This conceptual link is supported by empirical research, which indicates that firms utilising GF and FinTech jointly have a higher level of SP, such as reducing greenhouse gas, enhancing stakeholder engagement, and increasing reputation value (Carè et al., 2023). By taking up FinTech, institutional capacity to monitor, administer, and grow green projects and make financial interventions more effective is strengthened (Sadiq et al., 2024). Thus, embracing FinTech is not a matter of choice but a business necessity that, through the means of GF, a positive impact on the environment and society is demonstrated (Chaklader et al., 2023). Thus, we hypothesised that:

H4 FA mediates between GF and sustainable performance.

Figure 1 Research model



3 Methodology

This study employed a quantitative, cross-sectional research design to examine the hypothesised relationships among FA, GF, OI, and sustainable performance in Pakistani manufacturing SMEs. A cross-sectional approach is perfect for evaluating causal relationships between many latent dimensions at the same time and for getting insights that may be used in other situations when resources are limited (Hair et al., 2019). Pakistan was selected as the empirical setting due to the central role of SMEs in its economy, contributing approximately 40% to national GDP and 78% to non-agricultural employment. Despite their economic significance, these firms face structural barriers such as limited access to finance and technological capacity, which impede sustainable development. In line with the country's alignment with the United Nations' Sustainable Development Goals (SDGs), the diffusion of Industry 4.0 technologies, particularly FinTech applications such as digital lending and algorithmic credit scoring, has become increasingly relevant for enabling sustainability transitions (Pizzi et al., 2021a, 2021b).

A structured, self-administered questionnaire was used to collect primary data. Two academic experts and four SME managers were used to pre-test the instrument to ascertain the content validity. The last survey was conducted among SME managers who were knowledgeable enough in the operational and financial processes in their firm. To ensure representativeness and to reduce selection bias, simple random sampling was used. This approach provides a fair opportunity to be chosen by every unit in the population, hence, raising the external validity of the outcome. It followed the item-to-response criterion of 1:10, which is a well-known provision in structural equation modelling (SEM). Thus, 320 responses were required based on the 32 items employed in the constructs. A total of 550 questionnaires were distributed, and 340 valid responses were obtained, resulting in a response rate of 61.81%, which is considered good in organisational research. The data were gathered between January and April 2025, which had sufficient time coverage and reduced the bias of time. Partial Least Squares Structural Equation Modelling (PLS-SEM) software was used to test the highly proposed model. The SEM is also recommended in this research as it can estimate complex cause-effect relationships between latent variables, assess measurement and structural models within the same framework, and handle data that is not normally distributed (Hair et al., 2012).

3.1 Measurements

This study employed validated measurement scales adapted from prior literature to assess four core constructs: FA, sustainable performance, OI, and GF. All items were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

FA was operationalised based on six items developed by Almaqtari (2024) that evaluate the use of financial technology by SMEs to improve operations and financial decision-making. Sample item included: 'FinTech service is the first choice to pay for the future'. The 15 measurement items used to assess sustainable performance were all derived from Almaqtari (2024), who measured environmental, social, and economic components of the sustainability outcomes. Sample item included: 'Using environmentally sustainable services will help protect the environment'. OI was measured using six items derived from Niu et al. (2022). These items evaluate firms' internal capabilities to reconfigure processes, develop new business models, and implement change in response to digital transformation. Sample item included: 'Our company is innovative in the operation of the organisation'. GF was assessed with five items taken from Ye and Dela (2023). The items focus on a firm's access to and use of environmentally oriented financial instruments such as green bonds and sustainability-linked loans. Sample item included: 'Our company has allocated a specific budget for green projects and initiatives'.

4 Empirical results

4.1 Common method bias (CMB)

In the current study, the questionnaire survey was used to collect data about the independent and dependent variables within one source. Therefore, we are vulnerable to the CMB. The issue of CMB is severe and largely acknowledged, particularly when it comes to the employment of self-reported data (Podsakoff and Organ, 1986). The CMB issue was evaluated via a single Harman factor test. When the overall variance is less than 50%, a lack of CMB will be present, whereas when it is more than 50%, the presence of CMB will be indicated. Based on the empirical outcomes, it can be concluded that though a single variable explains 37.32% of all the variation, the overall results depict that there is no risk of CMB, and the data to be used in this study. The score of 37.32% falls short of the well-recognised criterion of 50%, indicating that no single factor is the predominant source of variation in the data. This indicates that CMB is improbable to undermine the validity of the data significantly, since respondents did not depend on a predominant answer pattern when completing the questionnaire (Podsakoff and Organ, 1986).

4.2 Measurement model

Table 1 demonstrates the desired reliability and validity indicators of construct assessment. The loading of the items included in the model is close to 0.50, which is the minimum acceptable level (Hair et al., 2016). The factor loading more than 0.7 is desirable (Vinzi, 2010), but when examining the outcomes of the studies conducted in social sciences, the outer loadings are often weaker. Instead of automatically deleting indicators, the effects of the deletion of the item on composite reliability, content, and

convergent validity shall be considered. All the indicators with outer loadings ranging between 0.40 and 0.70 may be subject to removal only when the deletion removes composite reliability or average variance extracted (AVE) above the suggested standard (Hair et al., 2016). SP and OI dropped out since they had low factor loading below the accepted level of 0.60. The removal enhanced the internal consistency and convergent validity of the constructs, so that these indicators could only take part in the measurement model (Hair et al., 2019). In the proposed research, the exclusion of the items (GF5 = 0.472, IO3 = 0.621, and IO4 = 0.642) would not have significant improvements in the composite reliability and AVE since the values of the construct were already higher than the suggested standard. The reliability was determined based on Cronbach alpha (or rho a) and composite reliability; the statistics of the two measures exceeded the stipulated 0.700 (Wasko and Faraj, 2005). The returned rho_a value was between Cronbach alpha and composite reliability (Sarstedt et al., 2017); also, above the 0.70 mark, this parameter points to good reliability (Henseler et al., 2016). The convergent validity was adequate since AVE was greater than 0.50. The findings reveal that the scale model is associated with high internal consistency and reliability.

Table 1 Validity statistics

Variables	*Items*	*Factor loadings*	*VIF*	*Cronbach alpha*	*CR*	*AVE*	R^2
Fintech adoption (FA)				0.927	0.943	0.734	
	AD1	0.841	2.929				
	AD2	0.894	4.125				
	AD3	0.860	2.768				
	AD4	0.849	2.518				
	AD5	0.817	2.542				
	AD6	0.877	3.386				
Green finance (GF)				0.760	0.836	0.512	0.118
	GF1	0.709	1.615				
	GF2	0.805	1.758				
	GF3	0.798	1.891				
	GF4	0.743	1.640				
	GF5	0.472	1.263				
Organisational innovation (OI)				0.772	0.823	0.542	0.258
	IO1	0.869	1.291				
	IO2	0.784	1.728				
	IO3	0.621	1.563				
	IO4	0.642	1.809				
Sustainable performance (SP)				0.912	0.930	0.655	0.405
	SP10	0.760	3.844				
	SP12	0.866	4.452				
	SP13	0.746	1.748				
	SP14	0.845	2.861				
	SP15	0.761	3.946				
	SP2	0.810	2.284				
	SP7	0.867	4.433				

4.3 Discriminant validity

The study uses two famous techniques, Fornell-Larcker criteria and heterotrait-monotrait (HTMT) correlation ratio, to determine the extent to which the study variables can be relied upon as discriminants. As the results of Table 2 indicate, all constructs have minimal construct correlation lower than the square root of AVE (Fornell and Larcker, 1981). Each of the HTMT scores was below 0.85 (Henseler et al., 2015), which confirmed that the discriminant validity was established. According to Hair et al. (2012), values of VIF that are less than 5 indicate multicollinearity in the variables of the given study. The observed results revealed that the value of VIF is less than 5, indicating that the variables were real (see Table 1). The discriminant validity results confirm that the constructs are distinct from one another, as demonstrated by both the Fornell-Larcker and HTMT criteria. This distinction ensures that each construct measures a unique concept, allowing for unbiased and meaningful estimation of relationships within the structural model.

Table 2 HTMT and Fornell Larker criteria

	FA	*GF*	*OI*	*SP*
Fornell-Larcker criterion				
Fintech adoption (FA)	0.857			
Green finance (GF)	0.344	0.716		
Organisation innovation (OI)	0.508	0.360	0.736	
Sustainable performance (SP)	0.570	0.403	0.481	0.809
HTMT criterion				
Fintech adoption (FA)				
Green finance (GF)	0.387			
Organisation innovation (OI)	0.451	0.351		
Sustainable performance (SP)	0.606	0.450	0.407	

4.4 Predictive relevance affects size

Each path coefficient in the structural model should have its f^2 effect size calculated (Henseler et al., 2016, and f^2 values exceeding 0.35, 0.15, and 0.02 indicate large, moderate, and small effect sizes (Cohen, 2001). The f^2 value determines whether independent constructs affect dependent constructs (Götz et al. 2010). 2010). The findings demonstrate that FA reveals a small connection to GF (0.134) yet shows moderate links with both OI (0.348) and sustainable performance (0.189) (Table 3). The f^2 values indicate the strength of the impact each exogenous variable has on its respective endogenous construct. Small values (FA → GF = 0.134) suggest modest yet meaningful contributions, while medium values (FA → OI = 0.348) reflect more substantial predictive influence. Among all relationships, FA → OI shows the highest effect size, highlighting that OI is a pathway through which FA drives sustainability, emphasising the importance of internal transformation in leveraging digital tools for sustainable outcomes. The blindfolding procedure derived from previous research

enabled this study to calculate Q^2 values for the PLS path model to evaluate predictive relevance (Hair et al., 2019). The Q^2 value in this model must exceed zero (0) according to Chin (2009). Cohen (2013) establishes that Q^2 must surpass 0.02 for small predictive relevance and scale up to 0.15 for medium cases and 0.35 for large cases. The Q^2 values from this analysis showed GF (0.104) and OI (0.246), along with sustainable performance (0.314). Q^2 reveals that the model's endogenous elements serve as predictive indicators. The model provides predictive relevance when the Q^2 value exceeds zero. This finding establishes strong predictive power within the constructs. The conceptual framework presented in this study enables the prediction of endogenous constructs (Cohen, 2013).

Table 3 Effect size

Variables	*GF*	*OI*	*SP*
Fintech adoption (FA)	0.134	0.348	0.189
Green finance (GF)			0.051
Organisation innovation (OI)			0.052

4.5 Hypotheses results

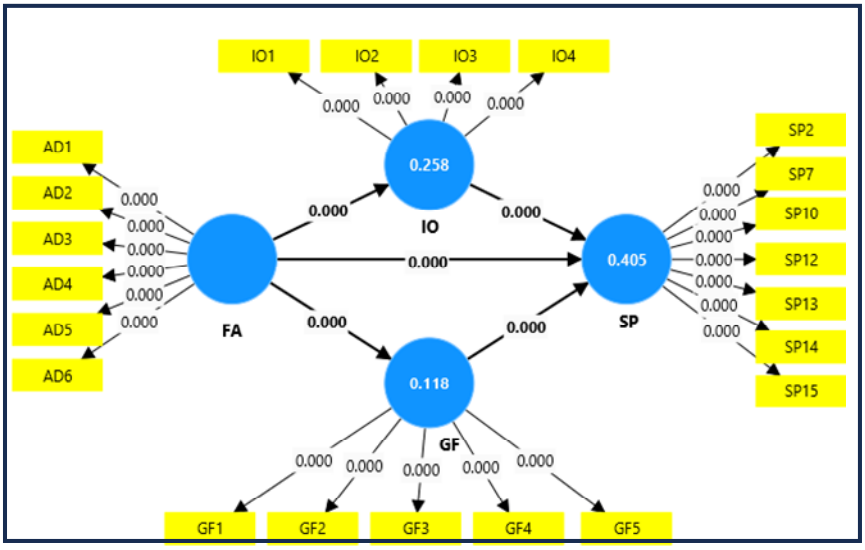
The results clearly show strong support for H1, confirming the direct positive effect of FA on SP. Meanwhile, H2, H3, and H4 demonstrate partial mediation, indicating that while FA directly enhances sustainability, its impact is also transmitted through Innovation and GF. These findings reinforce the significance of digital capabilities and financial mechanisms as complementary enablers of sustainable outcomes in SMEs. The research design incorporated SEM and path analysis to validate the proposed research hypotheses following the implementation of the measurement model in the previous section. The study has computed t-values and p-values to validate or reject the proposed hypotheses by using 1.96 as the cut-off value for t and 0.05 as the cut-off value for p. Table 4 displays empirical results demonstrating that AD produces a statistically significant impact on sustainable performance (β = 0.398, p-value = 0.000) as OI (β = 0.107, p-value = 0.001) and GF (β = 0.066, p = 0.003) work as intervening factors between AD-SP. Thus, Hypotheses 1, 2, and 3 are accepted. In line with Hypothesis 4, the empirical findings showed that AD significantly mediates between GF and sustainable performance (β = 0.137, p-value = 0.000).

Table 4 Results

	Original sample	*M*	*Standard deviation*	*T statistics*	*P values*
H1: FA → SP	0.398	0.398	0.069	5.772	0.000
H2: FA → IO → SP	0.107	0.108	0.031	3.479	0.001
H3: FA → GF → SP	0.066	0.068	0.022	3.021	0.003
H4: GF → AD → SP	0.137	0.140	0.034	3.991	0.000

Note: FA: FinTech adoption, SP: Sustainable performance, OI: Organisation innovation, GF: Green finance.

Figure 2 Structural equation modelling (see online version for colours)



5 Discussion

The theoretical and empirical evidence in the existing literature supports this positive link between FA and the SP of manufacturing SMEs. FinTech acts as a transformative tool that employs digital infrastructure for the delivery of services within the financial industry, which enables firms to improve the efficiency of their day-to-day operation, or access to improved data transparency and capital. FinTech reduces reliance on natural resources and facilitates the integration of renewable energy by enabling digital transactions and optimising resource efficiency (Nobanee et al., 2021). Given these capabilities, they are aligned with more general sustainability goals of encouraging sustainable consumption and production practices. The use of FinTech helps to enhance social sustainability, such as by increasing financial inclusion and transparency of corporates' social responsibility (Leong and Sung 2018). Ismail et al. (2022) point out that FinTech promotes investments in green projects and leads to resource efficiency. The findings of this study are in line with the previous results, assuming that digital finance acts as a facilitator of SP, as digital financial Innovation helps companies to invest in environmentally conscious actions (Deng et al., 2019; Croutzet and Dabbous, 2021). These findings hence corroborate earlier claims that FinTech serves as a financial innovation but a strategic enabler of environmental and social performance.

Our findings on the mediating effect of OI in the FinTech-sustainability link reinforce the idea that digital tools alone are insufficient. They must be accompanied by internal transformation to achieve strategic sustainability goals. The technological foundation of FA is insufficient; its effective utilisation depends on OI through changes in processes, routines, and business models (George, 2024). The results of this study are in line with those of Albort-Morant et al. (2016), which found that innovation practices mediate the relationship between digital technology and environmental performance. Hopalı et al. (2022) further indicated that Innovation is considered a dynamic capability of an

organisation in that it can reconfigure resources based on changes in the environmental and technological setting. Han et al. (2024) similarly found that innovation-oriented organisations are better positioned to leverage technology for achieving sustainability outcomes. The statement is reiterated by Quttainah and Ayadi (2024). Innovation serves as the organisational vehicle in making FinTech tools achieve tangible sustainability goals, as supported by this.

In the current research, the mediating role between sustainable performance and GF is examined, and the consistency of findings with the prior research is observed (Santos and Carvalho, 2025). Carcare et al. (2023) associated GF with investing the money in such projects that meet the environmental standards, such as energy-saving and pollution control. Previous literature indicates that FinTech improves the efficiency of GF by making applications freely accessible, transaction costs affordable, more transparent, and safer (Quttainah and Ayadi, 2024). The same can be achieved through the use of blockchain and digital auditing platforms as FinTech tools that would allow firms to document and offer evidence of the eco-friendly impact the financed project is having, thus enhancing accountability and reassuring investor confidence (Quttainah and Ayadi, 2024). A traditional loan may not be possible due to inadequate collateral to support the loan; thus, GF is feasible and possible for SMEs with low creditworthiness. According to the research of Santos and Carvalho (2025) and similar others, positive environmental consequences of the synergy of GF and digital technologies present positive environmental effects on the firms

The mediating effect of FA in the interconnection between GF and SP also provides an insight into the ways of incorporating financial nuts and bolts as well as digital processes into a sustainable framework. Although GF foresees the finance base, FinTech guarantees proper capital allocation by making it transparent, effective, and putting a calculable impact on the environmental aspect. Similar to Chaklader et al. (2023), there is great support for the statement that the impact of GF multiplies exponentially when sustainable investments can be adequately monitored, managed, and validated via digital technologies. In the absence of digital support, the initiatives of the GF can be inefficient, exhibit information asymmetries, and exhibit a low degree of traceability (Qing et al., 2024). FinTech systems can allow companies that aim to achieve SF or NFI in GF to use smart contracts, automated sustainability-linked pay-outs, and real-time environmental impact analysis with credible GF. Specifically, as indicated by Care et al. (2023), FinTech assists in spreading the effects of GF to SMEs that previously did not access them due to the inability to use such tools.

6 Conclusions

The primary aim of this study was to examine how FA, GF, and OI influence sustainable performance in manufacturing SMEs operating in Pakistan, with theoretical grounding in the RBV. By adopting a quantitative, cross-sectional research design and using PLS-SEM for data analysis, the study empirically tested four hypotheses. The results revealed that FA has a significant and direct positive effect on SP, supporting Hypothesis 1. OI and GF were found to mediate the relationship between FA and SP partially, confirming Hypotheses 2 and 3. The findings also validated Hypothesis 4, indicating that FA plays a significant mediating role in the relationship between GF and SP. These results collectively highlight the multifaceted role of FinTech as both a driver and an enabler of

sustainability through enhanced Innovation and access to GF. The study contributes uniquely to sustainability and SME literature by demonstrating how intangible digital and financial capabilities, when strategically aligned with innovation processes, can foster sustainable performance in resource-constrained environments. It extends the RBV by contextualising digital financial technologies as valuable and dynamic internal resources that support sustainability transitions. Moreover, the research addresses a notable gap by focusing on Pakistani SMEs, offering context-specific insights from a region often underrepresented in global discussions on digital transformation and sustainability. The study also provides empirical support for integrating FinTech into sustainability strategies within emerging economies, thereby informing both academic inquiry and managerial decision-making. Through its theoretical integration, empirical validation, and contextual relevance, this research advances the understanding of how SMEs can leverage internal capabilities to achieve long-term sustainability outcomes.

6.1 Theoretical implications

This study offers a significant theoretical contribution to the digital transformation, sustainability, and SMEs literature by extending the application of the RBV in the FA and SP context. Previous research has investigated the influence of FinTech on financial inclusion and operational efficiency. Yet, this study improves the understanding by elaborating on the nature of the fact that FinTech could be not only a technological tool, but a strategic resource enabling support for sustainability goals through the internal organisational mechanisms. The RBV is enriched by explicitly validating the mediating roles of OI and GF to prove that the resource of FinTech capabilities itself is not valuable, but the application of FinTech capabilities to innovate and finance, coherent with each other, makes it useful.

These findings serve the digital sustainability literature by offering FinTech as a dynamic enabler that leads to sustainable business operation through Innovation and financial restructuring. The findings of this study explain that a firm's competitive advantage is not just based on static resources, but on a firm's ability to dynamically configure its resources in response to changing external conditions. The confirmation of OI and GF as mediators further enriches the conversation about multi-dimensional resource orchestration, where adopting technology, the internal innovation capacity, and securing sustainability-oriented financial instruments are intertwined. Pizzi et al. (2021a) call for integrative models on the linkages between FinTech and ESG outcomes, and the research responds to this call. The study positions FinTech at the centre of a firm sustainability framework as a means to develop an enhanced view of firm sustainability that includes digital infrastructure, innovation routines, and capital access mechanisms. Thus, it broadens the existing boundaries of research in FinTech beyond financial performance to incorporate sustainability outcomes in the context of manufacturer SMEs operating in emerging economies.

6.2 Managerial implications

The findings of this study offer several critical implications for SME managers and decision-makers seeking to enhance SP in increasingly competitive and resource-constrained environments. First, the positive and significant impact of FA suggests that managers should proactively invest in and integrate digital financial

technologies such as digital lending, mobile payments, and algorithmic credit scoring into their operational frameworks. Such tools, though they aid in gaining access to non-traditional sources of financing, also increase accessibility of financial operations, omitting transaction costs, and enhancing financial transparency, which are important elements in sustaining financial investments in terms of sustainability. Second, inadequate mediation of OI in the relationship between FinTech and sustainability highlights the necessity of the managers developing an innovative culture in their firms. Agility and responsiveness can be increased by encouraging internal experimentation, introducing new technologies, and enhancing internal processes, which are required to meet the sustainability requirements of a firm. Third, the mediating role of GF explains the significance of conforming financial practices to serve environmental goals. One way is that managers ought to find green sources of funds, e.g., eco-loans, and climate-based financial schemes to help save the environment. To this end, they need to develop financial literacy and the capacity of their institutions to evaluate these developing financing tools critically. In addition to this, FinTech should not be regarded by managers as an operational IT process, but as a strategic capacity able to magnify Innovation and GF when used systemically. The insights also imply that there is a necessity for leadership commitment in spearheading digital transformation, cross-departmental collaboration, and linking sustainability goals with the strategic objectives. These internal actions are particularly more important to SMEs located in developing economies where there can be a shortage of external assistance and provision of institutional architecture. Thus, to be on the safe side and to be competitive and resilient in the global market that is continuously changing, managers need to focus on building digital capabilities, promoting innovation-oriented cultures, and establishing financing plans that comply with the concept of sustainable development.

6.3 Practical implications for manufacturing SMEs

The practical significance of the results of the study is direct and practical in terms of application to manufacturing SMEs operating in resource-limited environments and facing growing pressure on sustainability. Although theoretical knowledge based on the RBV is indispensable, applying this knowledge to a practical setting is necessary to convert strategic potential energy to practice.

FA is no longer a marginal improvement but a necessary strategic part of the digitalisation of the financial and operational procedures. The manufacturing SMEs, particularly in developing countries such as Pakistan, lack access to conventional financing channels due to a lack of collateral, credit risks, and bureaucratic hurdles. FinTech solutions like peer-to-peer (P2P) lending, invoice finance markets, blockchain-powered payment systems, and algorithmic credit scoring may be able to offer cost-effective, quick, and transparent solutions to financing working capital, procurement, and sustainable activities (Abbasi et al., 2021). SMEs that integrate such technologies into their operations can reduce transaction costs, enhance auditability, and improve financial agility. The study demonstrates that the benefits of FA are significantly amplified when combined with OI. This insight has clear industrial relevance. For example, manufacturing SMEs seeking to adopt smart manufacturing or circular production models must also innovate in how they manage workflows, cross-functional coordination, and supplier engagement. Embedding FinTech into existing enterprise resource planning (ERP) systems, automating sustainability reporting through AI, or

using real-time dashboards for green performance metrics are practical implementations of OI that this study supports.

GF emerges as a viable pathway for SMEs to access targeted funding for sustainability-focused upgrades such as energy-efficient machinery, pollution control technologies, or sustainable packaging solutions. By leveraging FinTech platforms that facilitate access to green bonds, sustainability-linked loans, and environmental subsidies, SMEs can bypass conventional financial exclusion. For instance, a manufacturing SME can use blockchain-enabled reporting to qualify for a green loan by demonstrating reduced energy consumption or emissions over time. FinTech thus becomes not just a financing channel but a compliance and monitoring tool that ensures alignment with environmental goals and lender requirements. Moreover, the mediating role of FinTech in GF suggests a transformation in how environmental commitments are operationalised. In practice, this could mean SMEs developing smart contracts that trigger financing tranches upon verification of environmental key performance indicators (KPIs) such as reductions in water usage, waste generation, or carbon footprint. Such mechanisms not only ensure financial discipline and accountability but also align the SME's operational model with broader stakeholder expectations.

6.4 Limitations and future directions

Although this study introduces a valuable contribution to this field, it is limited by its limitations. It only considers the manufacturing SMEs in Pakistan, which may limit the generalisation to other sectors or regions. Second, the cross-sectional design does not allow us to make causal inferences regarding the causal relationship between FA and SP. Since the research is cross-sectional, future research should consider longitudinal designs to capture dynamic temporal changes. Also, the research explored only two mediators: OI and GF. The method could be leveraged in future studies that look for other alternative mediators, such as digital literacy, environmental management practices, or supply chain transparency. The FinTech-sustainability nexus may also be moderated by potential moderators such as firm size, environmental turbulence, digital maturity, and/or regulatory support. Further validation and extension of the current findings could be done by expanding the study to other countries and using mixed methods. Future research should consider incorporating additional organisational-level variables such as digital maturity and organisational culture, which may significantly influence the FinTech-sustainability relationship. Digital maturity can moderate the effectiveness of FinTech implementation and its alignment with sustainability goals. Organisational culture may shape employee attitudes, decision-making, and the firm's overall responsiveness to green initiatives. By including these constructs in future research models, researchers can better understand the internal dynamics that either facilitate or hinder the transformation toward sustainable performance.

Authors' contributions

Conceptualisation: SR, SE, FE, and MBH. Methodology: SR, AK, FE, and MBH. Software: AK, and BMA. Validation: AK and MBH. Formal analysis: SR, SE, and FE. Investigation: FE, MBH, and SE. Resources: FE, SR, and MBH. Data curation: MBH, and AK. Writing – original draft: SR, SE, and FE. Writing – review and editing: SR, AK, and MBH. Visualisation: BMA, and AK. Project administration: SR and SE. Supervision: MBH. Funding acquisition: MBH. All authors have read and agreed to the published version of the manuscript.

Declarations

The authors declare no conflict of interest.

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