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Research article

FinTech adoption, Innovation, and performance in Saudi financial institutions

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Abstract: In this study, we examined the relationship between FinTech adoption, Innovation, and firm outcomes in the Saudi financial sector over the period 2018–2023, using a balanced panel of 39 financial institutions, including banks, insurance companies, and other financial service providers, yielding 234 firm-year observations. FinTech adoption was measured using a disclosure-based textual proxy derived from firms' annual reports, while Innovation was captured using an accounting-based proxy combining research and development expenditures and intangible assets. The empirical analysis combined partial least squares structural equation modeling (PLS-SEM) with two-way fixed-effects panel estimation. PLS-SEM was used to examine the hypothesized structural and indirect associations, while fixed-effects estimation provided a more conservative longitudinal assessment by exploiting within-firm variation and accounting for time-invariant firm heterogeneity and common year effects. The results indicated positive associations between FinTech adoption and Innovation, financial performance, and market valuation, with the contemporaneous FinTech associations also supported by the fixed-effects estimates. However, the Innovation-to-outcome relationships identified in PLS-SEM were not statistically significant in the fixed-effects specifications, indicating that the evidence regarding the Innovation-related pathway is sensitive to model specification. Overall, the findings provide stronger support for contemporaneous FinTech-related associations than for a robust Innovation-related intermediary pathway or persistent intertemporal relationships. The results therefore highlight the importance of cautious longitudinal evaluation of FinTech-related activities and firm outcomes in an emerging financial market undergoing rapid digital transformation.

Keywords: financial technology (FinTech); innovation; firm performance; PLS-SEM; Saudi financial institutions

JEL Codes: G20, O33, O31, L25, G32

Abbreviations: SAMA: Saudi Arabian Monetary Authority; FinTech: Financial Technology; DOI: Diffusion of Innovation; FSDP: Financial Sector Development Program; SPN: Saudi Payments Network; ROE: Return on Equity; VIF: Variance Inflation Factor; GoF: Goodness-of-Fit; GDP: Gross Domestic Product; RBV: Resource-Based View; PLS-SEM: Partial Least Squares Structural Equation Modeling; AI: Artificial Intelligence; ROA: Return on Assets; INNOV: Innovation; HTMT: Heterotrait-Monotrait

1. Introduction

The rapid advancement of financial technology (FinTech) has fundamentally transformed the structure and operations of modern financial systems. Through the adoption of digital platforms, artificial intelligence, blockchain technologies, and data-driven financial services, FinTech has reshaped how financial institutions deliver services, manage risks, and interact with customers (Gomber et al., 2018; Thakor, 2020). These developments have been particularly important in emerging economies, where digital financial solutions are increasingly viewed as tools for enhancing efficiency, competitiveness, and financial inclusion (Chen et al., 2019).

Alongside technological transformation, Innovation has become increasingly important for firm performance in the financial sector. Innovation enables financial institutions to develop new products and services, improve operational processes, and adapt to changing regulatory and technological environments. Prior research indicates that innovation-related investments, including research and development activities and intangible resources, may be associated with firm value and long-term performance (Hall et al., 2010; Rosenbusch et al., 2011; Sorescu et al., 2011). However, despite the growing importance of FinTech, the mechanisms through which FinTech adoption is related to firm outcomes, particularly through Innovation, remain insufficiently understood.

The empirical literature on FinTech and firm performance reports mixed and sometimes contradictory findings. While several studies document positive relationships between digital financial technologies and profitability, efficiency, and market value (Philippon, 2016; Vives, 2019), others report limited or context-dependent relationships (Banna et al., 2021). These inconsistencies may reflect differences in research settings, observation periods, empirical methods, and the measurement of FinTech adoption. Moreover, although Innovation is frequently acknowledged as an important component of digital transformation, its role as a potential intermediary mechanism between FinTech adoption and firm outcomes has received relatively limited empirical attention in the financial-sector literature (Lee & Shin, 2018; Lee et al., 2021).

This research gap is particularly relevant in Saudi Arabia. As part of Saudi Vision 2030, the Saudi financial system has undergone rapid digital transformation, accompanied by substantial investment in FinTech solutions and digital financial services aimed at enhancing operational efficiency, service quality, and financial inclusion (Financial Sector Development Program [FSDP],

2021). Despite the strategic importance of these developments, empirical evidence on the relationships among FinTech adoption, Innovation, and firm outcomes in Saudi financial institutions remains limited. Although FinTech is widely recognized as a driver of innovation and transformation in financial services (Lee & Shin, 2018), research has largely emphasized the direct implications of FinTech adoption or examined Innovation and its performance consequences as a related but distinct research stream (Hall et al., 2010; Rosenbusch et al., 2011; Sorescu et al., 2011). Consequently, less attention has been devoted to examining whether Innovation constitutes an intermediary mechanism through which FinTech adoption is associated with financial performance and market valuation. This limitation is particularly important because innovation-related activities and intangible resources present well-established measurement challenges, which may partly explain why their intermediary role is less frequently incorporated into empirical FinTech models (Hall et al., 2010). In the Saudi context, where digital transformation has progressed rapidly within a highly regulated financial system, firm-level evidence on this potential mechanism remains especially limited. Examining Innovation as an intermediary mechanism therefore provides a means of moving beyond the direct FinTech–performance relationship and assessing how FinTech adoption may be associated with firm outcomes through innovation-related capabilities and investments.

Against this backdrop, we examine the relationships among FinTech adoption, Innovation, financial performance, and market valuation in Saudi financial institutions over the period 2018–2023. Specifically, we investigate the direct relationships between FinTech adoption and firm outcomes and examine Innovation as a potential intermediary mechanism in these relationships. FinTech adoption is captured using a disclosure-based textual proxy derived from firms' annual reports, while Innovation is represented by an accounting-based proxy reflecting R&D expenditures and intangible assets.

This study contributes to the literature in three main ways. First, we develop a firm-level disclosure-based textual measure of FinTech adoption, offering an alternative to narrow single-indicator proxies. Second, we examine Innovation as a potential intermediary mechanism linking FinTech adoption to financial performance and market valuation, providing a more nuanced understanding of the FinTech–Innovation–performance relationship. Third, we provide firm-level evidence from Saudi financial institutions, extending the literature to an emerging financial market undergoing rapid institutional and technological transformation and generating context-specific insights relevant to researchers, practitioners, and policymakers.

To address these objectives, we combine partial least squares structural equation modeling (PLS-SEM) with two-way fixed-effects panel estimation. PLS-SEM is used to examine the hypothesized structural and indirect associations, whereas the fixed-effects models provide a more conservative longitudinal assessment by exploiting within-firm variation and controlling for time-invariant firm heterogeneity and common year effects. Accordingly, greater interpretive weight is placed on relationships that remain consistent across the two empirical approaches.

The remainder of the paper is organized as follows: In Section 2, we review the relevant literature and develop the research hypotheses. In Section 3, we describe the research design, data, variable measurement, and empirical methodology. In Section 4, we present empirical results from PLS-SEM and fixed-effects panel analyses. In Section 5, we discuss the findings and their theoretical, managerial, and policy implications. In Section 6, we conclude the study, discuss its limitations, and identify directions for future research.

2. Literature review and hypotheses development

2.1. FinTech adoption, firm outcomes, and innovation

Financial technology (FinTech) has emerged as an important driver of transformation in the financial sector by reshaping traditional financial intermediation and altering firms' operational models. From a theoretical perspective, the Resource-Based View (RBV) provides a useful foundation for explaining how FinTech adoption may be associated with firm outcomes. RBV suggests that firms can achieve superior performance when they effectively deploy valuable and difficult-to-imitate resources, including technological capabilities and digital infrastructures. FinTech-related resources, such as advanced analytics, digital platforms, and automated financial services, may therefore enable financial institutions to improve operational efficiency, reduce transaction costs, and strengthen their competitive capabilities.

Empirical research generally points to potential performance benefits from FinTech adoption, although the evidence should not be interpreted as uniform across settings or outcome measures. Philippon (2016) emphasized the potential of digital financial technologies to reduce financial intermediation costs, while Thakor (2020) highlighted their implications for competition, efficiency, and innovation in financial services. Other studies associate digital financial development with improvements in financial services and firm outcomes (Chen et al., 2019; Vives, 2019). However, the magnitude and realization of these benefits may depend on the institutional setting, the type and maturity of technological adoption, and firms' ability to integrate digital technologies into their existing resources and processes. Thus, FinTech adoption should not be viewed as automatically translating into superior performance; rather, its performance implications are likely to depend on how effectively technological resources are deployed and complemented by organizational capabilities.

This distinction is particularly relevant when considering different dimensions of firm outcomes. Improvements in operational efficiency may be reflected in accounting-based financial performance, whereas investors may evaluate FinTech adoption differently when forming expectations about firms' future prospects, resulting in potentially different implications for market valuation. Moreover, FinTech adoption may contribute to the development of new products, processes, and technological capabilities, suggesting that Innovation may represent an important organizational response to digital adoption rather than merely an independent outcome. This perspective provides a basis for examining the direct relationships between FinTech adoption and firm outcomes and its relationship with Innovation.

In Saudi Arabia, the rapid digital transformation of the financial sector under Vision 2030 provides a relevant setting in which to examine these relationships. However, the potential benefits of FinTech adoption should be considered within the specific institutional and regulatory environment in which Saudi financial institutions operate. Accordingly, rather than assuming that digital adoption necessarily improves firm outcomes, we empirically examine whether FinTech adoption is positively associated with financial performance, market valuation, and Innovation.

H_{1a}: FinTech adoption is positively associated with firm financial performance.

H_{1b}: FinTech adoption is positively associated with market valuation.

H_{1c}: FinTech adoption is positively associated with Innovation.

2.2. FinTech adoption and innovation

Beyond its potential direct association with firm outcomes, FinTech adoption may also contribute to the development of Innovation within financial institutions. From a Diffusion of Innovation (DOI) perspective, the adoption and assimilation of new technologies can facilitate organizational learning, experimentation, and changes in established processes and practices. Digital financial technologies may therefore provide financial institutions with opportunities to reconfigure internal processes, strengthen data-driven decision-making, and develop new or improved products and services.

Research generally supports a connection between digital technologies and Innovation, although technology adoption alone should not be assumed to generate Innovation automatically. Lee and Shin (2018) emphasize the role of FinTech in enabling new business models and transforming the financial-services ecosystem, while Mikalef et al. (2020) highlighted how digital and data-related capabilities can support organizational capabilities associated with innovation. Evidence from financial-sector settings also suggests that the implications of digitalization may depend on firms' ability to integrate technological resources into their organizational processes and respond to competitive and institutional conditions (Banna et al., 2021). Taken together, these studies suggest that the relationship between FinTech adoption and Innovation is contingent on organizational assimilation and complementary capabilities rather than being a mechanical consequence of technology adoption.

This distinction is particularly relevant in the Saudi financial sector, where rapid digital transformation creates opportunities for financial institutions to invest in digital infrastructure, analytics, and automation. Furthermore, operating within a regulated institutional environment means that the translation of technological adoption into Innovation may depend on how effectively firms integrate these technologies into their resources, processes, and strategic activities. Accordingly, we empirically examine whether greater FinTech adoption is positively associated with Innovation rather than assuming that digital adoption necessarily results in stronger innovation capability.

H_{1c}: FinTech adoption is positively associated with Innovation.

2.3. Innovation, financial performance, and market valuation

Innovation is widely regarded as an important organizational capability, particularly in knowledge-intensive and technology-driven industries. From an RBV perspective, innovation-related resources, including organizational know-how, technological capabilities, and intangible assets, may contribute to competitive advantage by enabling firms to differentiate their offerings, improve operational processes, and respond to changing market conditions. However, the performance implications of Innovation may vary depending on the nature of innovation-related investments, the outcome measure considered, and the time required for such investments to generate economic benefits.

Empirical research generally indicates a positive relationship between Innovation and firm outcomes, although the magnitude and timing of this relationship are not necessarily uniform. Hall et al. (2010) highlighted the contribution of innovation-related investment to productivity and long-term firm performance while emphasizing the challenges involved in evaluating the returns to innovation. Rosenbusch et al. (2011) provided meta-analytic evidence of a generally positive Innovation–performance relationship, but showed that its strength varies across organizational and contextual conditions. Sorescu et al. (2011) further illustrated that the economic value associated with Innovation can depend on how

markets evaluate firms' innovation-related activities and their expected future benefits. Taken together, this literature suggests that Innovation may be associated with firm outcomes, while its implications can differ across firms, performance dimensions, and contexts.

This distinction is particularly relevant in financial institutions, where innovation-related investments may affect accounting-based performance and market valuation through different channels. Improvements in products, processes, and service delivery may contribute to operational efficiency and profitability, whereas market participants may respond to the expected future value and strategic implications of innovation-related activities. In the Saudi financial sector, ongoing technological transformation provides a relevant setting for examining whether Innovation is associated with financial performance and market valuation rather than assuming that its benefits are immediate or uniform across outcome measures.

H_{2a}: Innovation is positively associated with firm financial performance.

H_{2b}: Innovation is positively associated with market valuation.

2.4. Firm characteristics and firm outcomes

Firm characteristics represent an important source of heterogeneity in financial and market outcomes because firms differ in their resource endowments, operating conditions, growth opportunities, and financial capacity. From an RBV perspective, such differences may affect firms' ability to deploy resources effectively and generate economic value. Firm size, growth, and internally generated financial resources may therefore be relevant when examining differences in financial performance and market valuation alongside FinTech adoption and Innovation.

Firm size is particularly relevant because larger firms may benefit from greater resource availability, economies of scale, and stronger capacity to undertake technological and organizational investments. However, the relationship between size and firm outcomes is not necessarily uniform. Research shows that firms of different sizes face different financing constraints and growth conditions, implying that size may shape performance through several competing mechanisms (Beck et al., 2005; Beck et al., 2008). Growth characteristics may similarly reflect differences in expansion opportunities and operating dynamics, while cash-flow-related characteristics capture firms' capacity to generate internal financial resources that can support investment and ongoing operations. Consequently, these characteristics may be associated with accounting-based performance and investors' assessment of firm value.

The relevance of these characteristics may be particularly pronounced in the financial sector, where firms differ substantially in scale, resource availability, and their capacity to absorb technological and innovation-related investments. Rather than assuming a uniform directional effect, we therefore account for firm characteristics as additional firm-level factors that may be associated with financial performance and market valuation. Incorporating these characteristics also helps distinguish the relationships associated with FinTech adoption and Innovation from broader cross-firm heterogeneity.

H_{3a}: Firm characteristics are associated with firm financial performance.

H_{3b}: Firm characteristics are associated with market valuation.

2.5. Innovation as a mediating mechanism between FinTech adoption and firm outcomes

While researchers have extensively examined the direct relationship between FinTech adoption and firm outcomes, less attention has been devoted to the organizational mechanisms through which this relationship may operate. Innovation provides a plausible intermediary mechanism because the adoption of digital technologies may create opportunities for financial institutions to redesign processes, integrate data, develop new services, and strengthen organizational capabilities. However, FinTech adoption does not necessarily generate performance benefits automatically; such benefits may depend partly on whether technological adoption is translated into innovation-related capabilities and activities.

The Diffusion of Innovation (DOI) theory and the Resource-Based View (RBV) provide complementary explanations for this intermediary mechanism. DOI helps explain the adoption, diffusion, and organizational assimilation of new financial technologies, suggesting that FinTech adoption can facilitate experimentation, learning, and the development of new organizational practices. RBV, in turn, explains how these technological resources may contribute to firm outcomes when they are combined with valuable organizational capabilities and innovation-related resources. Viewed jointly, DOI explains how FinTech technologies are adopted and assimilated, whereas RBV explains how their integration into innovation-related capabilities may be associated with financial and market outcomes. This theoretical complementarity provides a basis for considering Innovation as an intermediary mechanism between FinTech adoption and firm outcomes rather than assuming a purely direct technology–performance relationship.

Empirical research provides support for elements of this mechanism, although direct evidence on the full mediation pathway remains comparatively limited. Vives (2019) highlighted the role of digital technologies in reshaping competition, efficiency, and innovation in financial services, while Mikalef et al. (2020) emphasized the importance of complementary organizational and digital capabilities in translating technological resources into business value. Taken together, these studies suggest that the performance implications of digital technologies may depend on the organizational capabilities developed around them. Nevertheless, this evidence does not establish that Innovation uniformly mediates the FinTech–performance relationship across institutional settings, leaving the intermediary mechanism open to empirical examination.

This issue is particularly relevant in the Saudi financial sector, where FinTech adoption has expanded alongside broader national digital-transformation initiatives. The institutional and regulatory characteristics of the sector may shape how financial institutions translate technological adoption into innovation-related capabilities and, subsequently, into financial and market outcomes. Accordingly, we examine whether Innovation serves as an intermediary mechanism linking FinTech adoption to financial performance and market valuation.

More specifically, the two perspectives are integrated sequentially rather than operating as parallel explanations. DOI explains the organizational process through which FinTech-related technologies are adopted and assimilated into firms' routines and activities. Such assimilation can stimulate organizational learning, experimentation, and changes in processes, thereby creating a need for complementary innovation-related investments and intangible capabilities. RBV extends this explanation by clarifying why technology adoption alone may be insufficient to generate superior firm outcomes: Technological resources need to be combined with firm-specific knowledge, intangible resources, and organizational capabilities that enable their effective deployment. Accordingly, DOI primarily explains the transition from technology adoption and assimilation toward innovation-related

investment and capability development, whereas RBV explains how these complementary resources may be associated with financial performance and market valuation. The Innovation-related pathway therefore represents the theoretical interface between the two perspectives, linking the assimilation process emphasized by DOI with the capability-based value-creation logic emphasized by RBV. This theoretical integration describes the proposed mechanism linking the constructs and does not imply that organizational assimilation is directly measured by the disclosure-based FINTECH proxy.

H_{4a}: Innovation mediates the relationship between FinTech adoption and firm financial performance.

H_{4b}: Innovation mediates the relationship between FinTech adoption and market valuation.

2.6. Summary of the conceptual framework

Based on the reviewed literature and theoretical foundations, we propose the conceptual framework presented in Figure 1. The framework distinguishes two complementary dimensions of firm outcomes: accounting-based financial performance, represented by ROA and ROE, and market valuation, represented by Tobin's Q. FinTech adoption is hypothesized to be directly associated with both dimensions of firm outcomes and with Innovation, while Innovation is hypothesized to be associated with financial performance and market valuation. In addition, Innovation is examined as a potential intermediary mechanism linking FinTech adoption to these outcomes.

The framework integrates the Resource-Based View (RBV) and Diffusion of Innovation (DOI) perspectives in a complementary manner. DOI provides a basis for understanding the adoption and organizational assimilation of FinTech, whereas RBV explains how technological resources, when combined with innovation-related capabilities, may be associated with firm outcomes. Firm characteristics are also incorporated to account for firm-level heterogeneity and are hypothesized to be associated with financial performance and market valuation. Accordingly, the framework distinguishes accounting-based financial performance from external market valuation while considering the direct, indirect, and firm-specific relationships underlying the FinTech–Innovation–firm outcome nexus.

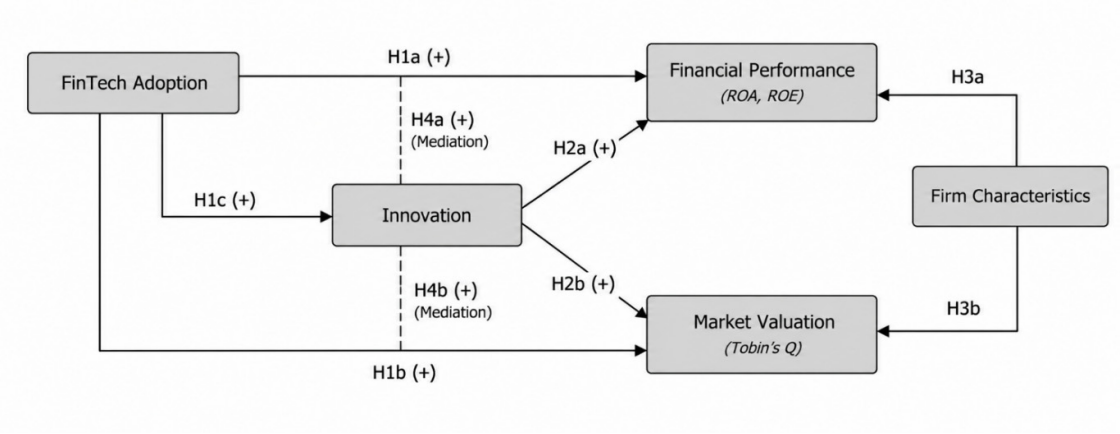


Figure 1. Conceptual framework of the study.

3. Methodology

3.1. Research design and data

In this study, we employ a quantitative research design to examine the direct and indirect relationships among FinTech adoption, Innovation, financial performance, and market valuation in the Saudi financial sector. The analysis is based on secondary firm-level data for 39 financial institutions listed on the Saudi Exchange (Tadawul), including banks, insurance companies, and other financial service providers. The study covers six fiscal years from 2018 to 2023, yielding a balanced panel of 234 firm-year observations (39 institutions × 6 years).

The 2018–2023 period corresponds to a phase of accelerated digital transformation in the Saudi financial sector following the launch of Saudi Vision 2030 and the development of national FinTech initiatives. Financial and accounting data are obtained primarily from firms' audited annual reports and disclosures available through the Saudi Exchange (Tadawul). FinTech adoption is measured using a disclosure-based textual proxy constructed from the Board of Directors' reports contained in firms' annual reports, as described in Section 3.2.1. Innovation and the remaining firm-level variables were constructed from the corresponding accounting and financial information reported in these sources.

The balanced panel of 234 firm-year observations is used for the PLS-SEM analysis and the contemporaneous two-way fixed-effects specifications. For the one-year-lagged and reverse-prediction analyses, constructing lagged variables removes the first annual observation for each of the 39 institutions, resulting in 195 firm-year observations. The relatively limited cross-sectional dimension of the panel (39 institutions) and the six-year observation window should be considered when evaluating the precision of the panel estimates. Although the balanced panel provides 234 firm-year observations, the fixed-effects estimates are identified primarily from within-firm variation over time. Consequently, the ability of these models to detect relationships may be constrained when the variables of interest exhibit limited within-firm variation over the study period. The use of firm-clustered standard errors and complementary wild-cluster bootstrap inference is intended to provide more reliable statistical inference given the relatively limited number of firm clusters. Nevertheless, these procedures do not eliminate the statistical limitations associated with the sample size and time dimension, and the fixed-effects estimates are therefore interpreted cautiously.

3.2. Variables and measurement

3.2.1. FinTech adoption (FINTECH)

FinTech adoption is measured using a disclosure-based textual proxy constructed from the Board of Directors' reports of the sampled financial institutions. Following the dictionary-based textual approach employed in prior FinTech research (Liu, Nikbakht, & Zhou, 2023), FinTech-related disclosure is identified using a predefined dictionary of terms and expressions associated with financial technologies.

The textual analysis is implemented in Python. Text is extracted from the Board of Directors' reports using PyPDF2 and preprocessed by converting the extracted content to lowercase, removing punctuation, and excluding common words. The cleaned text is then transformed into unigrams, bigrams, and trigrams using NLTK. FinTech-related occurrences are identified through exact matching with the predefined FinTech-related terms.

Two textual measures are generated. FinTech_counts captures the raw frequency of FinTech-related terms identified in each report, whereas FINTECH is the length-normalized measure used in the empirical analysis. Because raw keyword frequencies are mechanically affected by document length, FINTECH is normalized by the number of processed words in each report as follows:

$$FINTECH_{\mathrm{it}} = (FinTechMatches_{it} \,/\, ProcessedWord_{\mathrm{it}}) \times 1{,}000 \quad (1)$$

where $FinTechMatches_{it}$ denotes the total number of FinTech-related unigram, bigram, and trigram occurrences identified in the Board of Directors' report of firm i in year t, and $ProcessedWord_{\mathrm{it}}$ denotes the total number of words remaining after preprocessing. $FINTECH_{\mathrm{it}}$, therefore, represents the number of FinTech-related occurrences per 1,000 processed words. The resulting FINTECH measure is thus based on the normalized frequency of predefined FinTech-related terms.

To ensure consistency in measurement, the same predefined dictionary, preprocessing procedure, exact-matching criteria, and normalization rule are applied uniformly across all firm-year reports. The dictionary-based approach follows Liu, Nikbakht, and Zhou (2023), while normalization by processed document length improves comparability across firms and years by reducing the mechanical influence of differences in report length.

Higher FINTECH values indicate a greater concentration of FinTech-related disclosure. Given its disclosure-based nature, FINTECH is interpreted as a proxy for the intensity of FinTech-related disclosure associated with firm-level FinTech adoption rather than as a direct measure of actual FinTech investment or implementation.

3.2.2. Innovation (INNOV)

Innovation is measured using an accounting-based proxy constructed from reported research and development (R&D) expenditures and intangible assets. Specifically, the variable is calculated as the natural logarithm of the combined value of R&D expenditures and intangible assets:

$$INNOV_{\mathrm{it}} = ln(1 + R\&D_{\mathrm{it}} + \mathrm{IntangibleAssets}_{\mathrm{it}}) \quad (2)$$

where $R\&D_{\mathrm{it}}$ represents reported research and development expenditure and $\mathrm{IntangibleAssets}_{\mathrm{it}}$ represents reported intangible assets for firm i in year t. The constant of one is added to accommodate zero-valued observations and ensure that the logarithmic transformation is defined, while the log transformation reduces the influence of extreme monetary values and positive skewness in the underlying accounting data.

The use of this measure is grounded in the distinction between innovation inputs and innovation outputs. R&D expenditure is widely recognized as an important input into firms' innovation activities and has been extensively used in empirical research examining innovation investment and its economic returns (Hall et al., 2010). The Oslo Manual similarly identifies R&D as a core innovation activity while recognizing that firms' innovation efforts may involve other knowledge-based activities and resources, including software development, databases, and intellectual property (OECD/Eurostat, 2018).

This broader perspective is particularly relevant to financial institutions, where innovation may be embodied in digital systems, software, intellectual property, and other knowledge-related and technology-related intangible resources rather than being fully reflected in formally reported R&D expenditure. Consequently, relying exclusively on R&D expenditure may understate observable innovation-related investment in this sector.

In the sample, R&D expenditures and intangible assets also exhibit heterogeneous reporting patterns across firms and years, with some firm-year observations reporting low or zero values for one component while reporting positive values for the other. Combining the two components therefore provides a broader accounting-based proxy for observable innovation-related investment and accumulated intangible capability than relying exclusively on either component.

Importantly, the measure is not interpreted as a direct measure of realized innovation output. Rather, it captures observable accounting-based resources associated with firms' innovation-related investment and intangible capability. This interpretation is consistent with the broader innovation-measurement literature, which distinguishes resources and activities devoted to innovation from realized innovation outcomes (Hall et al., 2010; OECD/Eurostat, 2018).

3.2.3. Financial performance and market valuation

Firm outcomes are assessed using three complementary indicators that distinguish accounting-based financial performance from market-based valuation. Return on Assets (ROA) is used to capture operational profitability relative to the firm's asset base, while Return on Equity (ROE) reflects profitability from the shareholders' perspective. Both measures are widely used in studies of banking and financial institutions (Wetzels et al., 2009; Thakor, 2020).

Tobin's Q is included as a complementary market-based valuation measure rather than as a direct measure of accounting profitability. In this study, Tobin's Q is calculated as the market value of equity plus total debt, divided by total assets. Unlike ROA and ROE, which are derived from accounting information and reflect realized financial performance, Tobin's Q incorporates market expectations regarding the firm's future prospects and the value attributed to its resources and capabilities (Villalonga, 2004). Its inclusion is particularly relevant to the present study because FinTech adoption and innovation-related investments may generate benefits that are not immediately reflected in current accounting earnings but may nevertheless be incorporated into market valuation.

Furthermore, the interpretation of Tobin's Q requires particular caution in financial institutions. Banks, insurance companies, and other financial service providers have balance-sheet structures in which financial assets and liabilities constitute a substantial part of their operations, making the interpretation of asset-based market valuation ratios different from that of non-financial firms. Accordingly, Tobin's Q is not treated as a substitute for ROA or ROE, nor as a standalone indicator of financial performance. Instead, it is used as a complementary measure of market valuation, enabling the analysis to distinguish accounting-based performance and external market assessment. This distinction is maintained throughout the empirical analysis and interpretation of the results.

The combined use of ROA, ROE, and Tobin's Q therefore provides complementary perspectives on firm outcomes: ROA captures asset-based profitability, ROE captures shareholder profitability, and Tobin's Q captures market valuation. This multi-measure approach reduces reliance on any single performance indicator and enables us to examine whether the relationship between FinTech adoption and firm outcomes differs between accounting-based and market-based measures.

3.2.4. Control variables

Three firm-level control variables, firm size, growth, and cash flow, are included to account for observable firm characteristics that may be associated with both firms' capacity to undertake

technology-related and innovation-related activities and their financial outcomes. Firm size is measured as the natural logarithm of total assets and captures differences in organizational scale, resource availability, and operational complexity. Larger financial institutions may possess greater financial and technological resources to support digital and innovation-related investments, while size may be systematically associated with profitability and market valuation (Rajan & Zingales, 1995; Hall et al., 2010).

Growth is measured as the annual percentage change in sales revenue and captures differences in firms' expansion opportunities and operating dynamics. Firms experiencing stronger growth may face different investment requirements and may exhibit different financial performance and valuation patterns. Cash flow, measured as operating cash flow divided by total assets, captures internal liquidity and financing capacity. Firms with stronger internally generated resources may have greater capacity to finance technological and innovation-related investments while differing in their financial outcomes (Fazzari et al., 1988; Hall et al., 2010).

These three variables are used consistently as the firm-level controls across the empirical analyses. In the PLS-SEM specification, they are incorporated within the Firm Characteristics component to represent observable firm-level heterogeneity, whereas in the two-way fixed-effects specifications, they enter separately as time-varying covariates. This difference reflects the distinct modeling structures of the two empirical approaches rather than a change in the underlying set of control variables. The controls are included to reduce observable firm-level heterogeneity in the estimated associations and are not assigned a causal interpretation.

3.3. Analytical approach

The empirical analysis is conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4. The model is specified as a composite-based path model using observed variables and index-based measures rather than reflective latent constructs. This approach is appropriate for examining mediation relationships involving composite indicators and financial proxies within a predictive modeling framework.

Path coefficients are estimated using a bootstrapping procedure with 5,000 resamples. Model explanatory power is assessed using R^2 values, effect sizes are evaluated using f^2 statistics, and predictive relevance is examined using the Stone–Geisser Q^2 criterion.

3.4. Mediation analysis

The potential intermediary role of Innovation is assessed by examining the bootstrapped indirect relationships between FinTech adoption and firm outcomes through the Innovation proxy. A statistically significant indirect path is interpreted as evidence consistent with an indirect association within the PLS-SEM specification rather than as establishing causal mediation. The interpretation of these indirect relationships is subsequently considered alongside the fixed-effects results to assess their consistency across alternative empirical specifications.

3.5. Methodological justification

The empirical strategy combines PLS-SEM and two-way fixed-effects panel estimation as complementary approaches with distinct inferential roles. PLS-SEM is used to assess the hypothesized multivariate structural and indirect associations among FinTech adoption, Innovation, Firm Characteristics, Financial Performance, and Market Valuation within a unified model. This approach is particularly useful for examining interrelated pathways and indirect associations among composite and observed measures (Hair et al., 2021).

Furthermore, the longitudinal firm-year structure of the dataset requires an estimation approach that explicitly accounts for unobserved firm-specific heterogeneity. Accordingly, two-way fixed-effects models are employed to provide a more conservative longitudinal assessment by exploiting within-firm variation while controlling time-invariant firm characteristics and common year effects. The fixed-effects estimates are therefore given greater interpretive weight when assessing whether the relationships identified in the structural model remain evident under a more restrictive panel-data specification.

The two approaches are thus used jointly rather than hierarchically. PLS-SEM evaluates the hypothesized structural and indirect relationships, whereas fixed-effects estimation assesses the extent to which these relationships persist after accounting for firm and year heterogeneity. Differences between the two sets of results are explicitly considered in the interpretation of the findings rather than being treated solely as robustness qualifications.

3.6. Fixed-effects and temporal-ordering analyses

The panel-data analysis employs two-way fixed-effects models to provide a more conservative longitudinal assessment of the relationships examined in the structural model. The analysis uses the balanced firm-year panel of 234 observations, while the lagged specifications are based on 195 observations after constructing one-year lags.

The fixed-effects specifications include both firm and year effects. Firm fixed effects account for time-invariant institution-specific heterogeneity, whereas year fixed effects absorb common macroeconomic, regulatory, and market-wide shocks. Standard errors are clustered at the firm level to account for within-firm dependence over time.

The panel models examine Innovation, ROA, ROE, and Tobin's Q as separate dependent variables. FinTech adoption is the focal explanatory variable, while cash flow, growth, and firm size are included as time-varying firm-level controls. Innovation is additionally included in the ROA, ROE, and Tobin's Q specifications to assess whether the Innovation-to-outcome relationships identified by PLS-SEM remain evident when estimation relies on within-firm variation over time. Because inference is based on 39 firm clusters, the statistical significance of the focal FinTech and Innovation coefficients is additionally evaluated using a null-imposed wild-cluster bootstrap with 9,999 Rademacher replications.

Additional one-year-lagged and reverse-prediction specifications are estimated to examine temporal ordering and the extent to which the contemporaneous associations persist over time. These analyses are used as diagnostic checks rather than as causal identification strategies. In particular, the absence of significant reverse-prediction relationships cannot rule out omitted time-varying variables, simultaneity, or measurement error. Similarly, lagging the FINTECH measure by one year does not by itself establish exogenous variation or causal direction. Because we do not employ an instrumental-variable approach, a quasi-experimental design, or another source of plausibly exogenous variation, the empirical estimates

are interpreted throughout as associations rather than causal effects. The temporal-ordering analyses therefore provide evidence on the persistence and sequencing of the observed relationships, but they do not identify causal effects.

Table 1. Variables and measurement.

Variable Type	Construct	Measurement / Operationalization	Rationale for Measurement	Supporting Literature
Independent	FinTech Adoption (FINTECH)	Disclosure-based textual proxy constructed from firms' Board of Directors' reports. FinTech-related unigram, bigram, and trigram occurrences are identified through exact matching with a predefined FinTech dictionary. The raw frequency (FinTech_counts) is normalized by the total number of processed words and expressed as FinTech-related occurrences per 1,000 processed words.	The textual measure captures the concentration of FinTech-related disclosure at the firm-year level. Normalization by processed document length reduces the mechanical influence of differences in report length and improves comparability across firms and years.	Liu, Nikbakht, & Zhou (2023)
Mediating	Innovation-related investment and intangible capability (INNOV)	ln(1 + R&D expenditures + intangible assets)	An accounting-based proxy for observable innovation-related investment and accumulated intangible capability rather than realized innovation output.	Hall et al. (2010); Rosenbusch et al. (2011); Hsu & Fang (2009); Mikalef et al. (2020)

Continued on next page

Variable Type	Construct	Measurement / Operationalization	Rationale for Measurement	Supporting Literature
Dependent	Financial Performance – ROA	Net Income / Total Assets	ROA reflects operational efficiency and asset utilization, widely used in banking and financial performance studies.	Wetzels et al. (2009); Thakor (2020)
	Financial Performance – ROE	Net Income / Shareholders' Equity	ROE captures shareholder profitability and return on invested capital, a key indicator in financial institutions.	Villalonga (2004); Chen et al. (2019)
	Market Valuation – Tobin's Q	(Market Value of Equity + Total Debt) / Total Assets	Tobin's Q provides a complementary market-based valuation measure that captures investors' assessment of the firm's future prospects. Given the distinctive balance-sheet structure of financial institutions, it is interpreted separately from the accounting-based performance measures ROA and ROE.	Villalonga (2004); Sorescu et al. (2011)
Control	Firm Size (SIZE)	ln(Total assets)	Controls for economies of scale, resource availability, and operational complexity.	Rajan & Zingales (1995); Hall et al. (2010)
	Growth (GROWTH)	Annual percentage change in sales revenue	Captures firm expansion opportunities and market dynamics affecting performance.	Fazzari et al. (1988); Chen et al. (2019)
	Cash Flow (CF)	Operating cash flow / Total assets	Reflects internal liquidity and financing capacity, influencing investment and performance outcomes.	Fazzari et al. (1988); Hall et al. (2010)

4. Results

4.1. Descriptive statistics

Table 2 reports the descriptive statistics of the study variables. Overall, the variables exhibit sufficient variability, indicating an adequate dispersion for multivariate analysis. The mean value of the FINTECH measure is 0.249, with a standard deviation of 0.247, indicating substantial variation in the intensity of FinTech-related disclosure across Saudi financial institutions. This variation suggests that the extent to which firms disclose FinTech-related terms and activities differs considerably across

the sample. Consistent with its construction, this measure is interpreted as a disclosure-based proxy and not as a direct measure of actual FinTech adoption or implementation.

Financial performance indicators show moderate profitability across the sample. The mean values of Return on Assets (ROA) and Return on Equity (ROE) are 0.256 and 0.236, respectively, indicating stable operational and shareholder performance. Tobin's Q has a mean value of 0.438, which is below one. Given the distinctive balance-sheet structure of financial institutions and the asset-based approximation of Tobin's Q employed in this study, this value is interpreted cautiously as a descriptive market-valuation ratio and should not be taken as evidence that market valuation exceeds the book value of assets. More generally, because the balance sheets of financial institutions differ substantially from those of non-financial firms, particularly in the composition and economic role of financial assets and liabilities, Tobin's Q is used here as a relative market-valuation indicator within the study sample rather than as a direct measure of conventional growth opportunities or excess market value.

The Innovation proxy, measured using the logarithm of R&D expenditures and intangible assets, displays substantial dispersion, with a mean of 11.343 and a relatively high standard deviation. This variation indicates heterogeneous levels of observable innovation-related investment and accumulated intangible capability across the sampled financial institutions. Consistent with its accounting-based construction, the measure should not be interpreted as capturing realized innovation output.

Table 2. Descriptive statistics.

Name	Mean	Median	Min	Max	STD	kurtosis	Skewness	Cramér-von Mises p value
Cash Flow	2.777	1.381	0.005	18.368	2.874	4.301	1.716	0.000
FinTech	0.249	0.142	0.000	1.491	0.247	1.153	1.000	0.000
Growth ratio	0.237	0.185	0.003	1.821	0.257	13.007	3.054	0.000
Q	0.438	0.325	0.010	2.437	0.450	4.344	1.947	0.000
ROA	0.256	0.044	0.005	0.990	0.352	−0.448	1.125	0.000
ROE	0.236	0.131	0.010	0.996	0.272	1.728	1.676	0.000
Size	23.070	21.320	14.537	32.667	4.782	−0.595	0.826	0.000
R&D + intangible Asset	11.343	14.283	0.000	24.471	7.716	−1.189	−0.528	0.000

4.2. Correlation analysis

Table 3 presents the Pearson correlation matrix for the study variables. The results show that FinTech adoption is positively correlated with firm financial performance indicators, particularly ROA and ROE. FinTech-related disclosure intensity also exhibits a positive association with the Innovation proxy, indicating that firms with greater FinTech-related disclosure tend to report higher levels of observable innovation-related investment and intangible capability.

The Innovation proxy is positively correlated with the financial performance measures and Tobin's Q, indicating that higher levels of observable innovation-related investment and intangible capability tend to be associated with stronger financial outcomes and market valuation within the sample. Control variables, including firm size, growth, and cash flow, also exhibit meaningful correlations with the performance indicators.

These bivariate correlations are reported for descriptive and exploratory purposes and should not be interpreted as evidence of causal relationships. The multivariate associations among the study variables are subsequently examined using the PLS-SEM structural model and the fixed-effects panel specifications.

To examine potential multicollinearity among the predictor constructs, Variance Inflation Factor (VIF) values are assessed. According to established thresholds in the PLS-SEM literature, VIF values below 3.3 indicate the absence of critical collinearity issues. The results show that all VIF values range from 1.12 to 2.48, which are well below the conservative threshold of 3.3. Therefore, multicollinearity does not appear to pose a concern for the structural model.

Table 3. Correlation matrix.

	Cash Flow	FinTech	Growth ratio	Q	ROA	ROE	Size	log R&D + intangible Asset
Cash Flow	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FinTech	0.255	1.000	0.000	0.000	0.000	0.000	0.000	0.000
Growth ratio	0.088	0.048	1.000	0.000	0.000	0.000	0.000	0.000
Q	0.268	0.274	0.178	1.000	0.000	0.000	0.000	0.000
ROA	0.242	0.639	0.159	0.304	1.000	0.000	0.000	0.000
ROE	0.153	0.395	0.174	0.272	0.634	1.000	0.000	0.000
Size	0.260	0.056	−0.012	−0.120	−0.168	−0.152	1.000	0.000
log R&D + intangible Asset	0.395	0.400	0.115	0.327	0.349	0.327	0.293	1.000

4.3. Structural model results

The hypothesized relationships are examined using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4 (Figure 2). Path coefficients were estimated using a bootstrapping procedure. Table 4 reports the coefficients of determination (R^2) for the endogenous constructs.

The R^2 value for innovation is 0.160, indicating that FinTech adoption explains 16% of the variance in innovation intensity. The R^2 for firm financial performance is 0.426, suggesting that FinTech adoption, innovation, and control variables jointly explain 42.6% of the variance in performance. Market valuation exhibits an R^2 value of 0.206, indicating moderate explanatory power.

Direct path estimates and hypothesis testing results are reported in Table 5. The results indicate that FinTech-related disclosure is positively and statistically significantly associated with firm financial performance ($\beta = 0.502$, $p < 0.001$). FinTech-related disclosure is also positively and statistically significantly associated with Innovation ($\beta = 0.400$, $p < 0.001$). Its direct association with market valuation is positive and marginally significant ($\beta = 0.135$, $p = 0.052$). Innovation is positively and statistically significantly associated with firm financial performance ($\beta = 0.121$, $p = 0.011$) and market valuation ($\beta = 0.207$, $p < 0.001$). Firm Characteristics, comprising firm size, growth, and cash flow, are also positively and statistically significantly associated with Financial Performance ($\beta = 0.230$, $p < 0.001$) and Market Valuation ($\beta = 0.284$, $p < 0.001$). These results indicate that observable differences in organizational scale, growth dynamics, and internal financing capacity are

systematically associated with firm outcomes within the PLS-SEM specification. The Firm Characteristics component is included primarily to account for observable firm-level heterogeneity rather than as a focal explanatory construct. Accordingly, these relationships are interpreted as conditional associations and not as causal effects. Overall, the structural-model results indicate that the focal FinTech- and Innovation-related associations are estimated while accounting for these relevant firm-level characteristics.

Table 4. Coefficient of determination (R^2).

Constructs relation	R^2	Result
Innovation	0.16	weak
Financial Performance	0.426	moderate
Market Valuation	0.206	moderate

Table 5. Hypothesis testing of direct relationship.

Hyp.	Relationship	Path Coefficient (β)	t-value	p-value
H1a	FinTech Adoption → Financial Performance	0.502***	8.839	<0.001
H1b	FinTech Adoption → Market Valuation	0.135*	1.947	0.052
H1c	FinTech Adoption → Innovation	0.400***	9.127	<0.001
H2a	Innovation → Financial Performance	0.121**	2.536	0.011
H2b	Innovation → Market Valuation	0.207***	4.042	<0.001
H3a	Firm Characteristics → Financial Performance	0.230***	3.967	<0.001
H3b	Firm Characteristics → Market Valuation	0.284***	3.867	<0.001

Note: β denotes the standardized path coefficient. ***p < 0.01, **p < 0.05, *p < 0.10. Hypotheses are considered supported at p < 0.10.

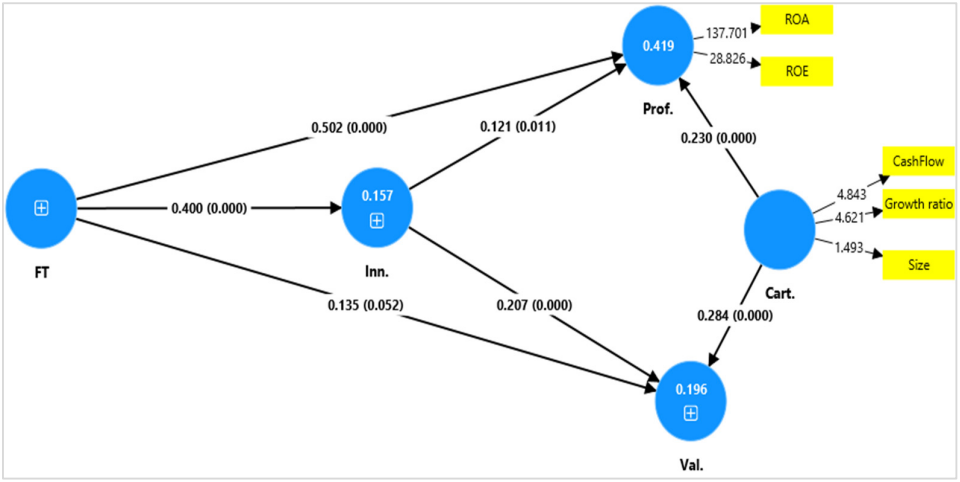


Figure 2. Structural model with p-values.

4.4. Mediation analysis

The mediation analysis examines whether the Innovation proxy represents a potential intermediary pathway in the relationship between FinTech adoption and firm outcomes. As reported in Table 6, the indirect relationship between FinTech adoption and financial performance through Innovation is positive and statistically significant ($\beta = 0.048$, $p = 0.009$). Similarly, the indirect relationship between FinTech adoption and market valuation through Innovation is positive and statistically significant ($\beta = 0.083$, $p < 0.001$). These results provide evidence consistent with an indirect Innovation-related association within the PLS-SEM specification. However, this evidence should be interpreted cautiously because the Innovation-to-outcome relationships are not statistically significant in the two-way fixed-effects specifications. Accordingly, the mediation evidence is sensitive to model specification and should not be interpreted as establishing a robust or causal mediation mechanism.

Total effects, reported in Table 7, show that the combined direct and indirect effect of FinTech adoption on firm financial performance is 0.550 ($p < 0.001$), while the total effect on market valuation is 0.218 ($p < 0.001$). These total-effect estimates summarize the combined direct and indirect associations identified within the PLS-SEM specification. However, given the lack of corresponding support for the Innovation-to-outcome relationships in the fixed-effects models, they should not be interpreted as confirming a robust intermediary mechanism across specifications.

Table 6. Significance of total indirect effect.

Hyp.	Relationship	Path Coefficient (β)	t-value	p-value
H4a	FinTech Adoption → Innovation → Financial Performance	0.048***	2.601	0.009
H4b	FinTech Adoption → Innovation → Market Valuation	0.083***	3.559	<0.001

Note: β denotes the standardized indirect effect. ***p < 0.01, **p < 0.05, *p < 0.10. Hypotheses are considered supported at p < 0.10.

Table 7. Total effect of (direct + indirect).

Relationship	Total Effect (β)	t-value	p-value
FinTech Adoption → Financial Performance	0.550***	10.814	<0.001
FinTech Adoption → Market Valuation	0.218***	3.652	<0.001

Note: β denotes the standardized total effect. ***p < 0.01, **p < 0.05, *p < 0.10.

4.5. Predictive relevance and robustness checks

Predictive relevance is assessed using the Stone–Geisser Q^2 statistic obtained through the blindfolding procedure. As reported in Table 8, all endogenous constructs exhibit positive Q^2 values, indicating satisfactory predictive relevance of the model.

To further assess the findings, one-year-lagged analyses are conducted to examine whether FinTech-related disclosure predicts subsequent Innovation and firm outcomes. The one-year-lagged

analyses provide a different pattern from the contemporaneous results. As reported in Table 10, lagged FinTech-related disclosure does not significantly predict subsequent Innovation (β = −0.158, p = 0.883), ROA (β = 0.026, p = 0.880), or Tobin's Q (β = −0.101, p = 0.597). For ROE, the lagged coefficient is negative and statistically significant (β = −0.230, p = 0.046). Thus, the positive contemporaneous associations are not reproduced when FinTech is lagged by one year. These findings substantially limit any interpretation of contemporaneous relationships as evidence of persistent intertemporal effects and do not support causal interpretation.

Second, a multi-group analysis (MGA) is performed to examine potential differences between banks and insurance companies. The results indicate no statistically significant differences between the two groups for the key structural paths, suggesting that the observed FinTech-Innovation-performance relationships do not differ significantly across these financial subsectors in Saudi Arabia.

Table 8. Values for predictive relevance and blindfolding.

Constructs relation	Q^2 predict	Result
Innovation	0.156	accepted
Financial Performance	0.392	accepted
Market Performance (Value)	0.144	accepted

4.6. Fixed-effects panel and temporal-ordering results

Two-way fixed-effects models are estimated using the full panel of 234 firm-year observations to provide a more conservative longitudinal assessment of the study relationships. The models include firm and year fixed effects, with standard errors clustered at the firm level. Given the relatively limited number of firm clusters (39), statistical inference for the focal coefficients is also assessed using a null-imposed wild-cluster bootstrap with 9,999 Rademacher replications.

As reported in Table 9, FinTech-related disclosure remains positively associated with Innovation, ROA, ROE, and Tobin's Q after controlling for time-invariant firm heterogeneity and common year effects. The estimated coefficients are 3.769 for Innovation, 0.739 for ROA, 0.276 for ROE, and 0.386 for Tobin's Q; the wild-cluster bootstrap p-values are 0.006, <0.001, 0.004, and 0.028, respectively. The 95% bootstrap confidence intervals exclude zero in all four cases. These findings indicate that the positive contemporaneous associations between FinTech adoption and the study outcomes are robust to the inclusion of firm and year fixed effects.

The two-way fixed-effects results provide support for the contemporaneous associations between FinTech adoption and the study outcomes. FinTech-related disclosure remains positively and statistically significantly associated with Innovation, ROA, ROE, and Tobin's Q after controlling for time-invariant firm heterogeneity and common year effects. However, the coefficients of Innovation are not statistically significant in the ROA (β = 0.003, p = 0.659), ROE (β = 0.010, p = 0.138), and Tobin's Q (β = 0.015, p = 0.144) equations. These more conservative fixed-effects estimates therefore do not reproduce the significant Innovation-to-outcome relationships identified by PLS-SEM. Accordingly, greater interpretive weight is placed on the fixed-effects evidence when assessing the robustness of the Innovation-related pathway, indicating that the mediation evidence is sensitive to model specification and should not be regarded as uniformly supported across estimation approaches.

Table 9. Panel-data robustness analyses using two-way fixed effects.

Variables	Innovation	ROA	ROE	Tobin's Q
FinTech adoption	3.769*	0.739*	0.276*	0.386
Clustered SE	(1.251)	(0.133)	(0.087)	(0.173)
Wild-bootstrap p-value	0.006	<0.001	0.004	0.028
95% bootstrap CI	[1.169, 6.586]	[0.464, 1.049]	[0.099, 0.478]	[0.038, 0.798]
Innovation	—	0.003	0.010	0.015
Clustered SE	—	(0.007)	(0.007)	(0.009)
Wild-bootstrap p-value	—	0.659	0.138	0.144
Cash Flow	0.204	0.008	0.004	0.011
Clustered SE	(0.094)	(0.006)	(0.005)	(0.010)
Growth	2.445	0.089	0.040	0.089
Clustered SE	(0.766)	(0.069)	(0.092)	(0.200)
Firm Size	0.552	−0.005	−0.001	0.020
Clustered SE	(0.165)	(0.007)	(0.006)	(0.010)
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	234	234	234	234
R^2	0.872	0.647	0.441	0.529
Within R^2	0.250	0.309	0.108	0.136

Notes: Two-way fixed-effects estimates are reported with standard errors clustered at the firm level in parentheses. Wild-cluster bootstrap inference for the focal FinTech adoption and Innovation coefficients is based on 9,999 Rademacher replications with 39 firm clusters. The 95% bootstrap confidence intervals reported for FinTech adoption correspond to the wild-cluster bootstrap procedure.

The control variables also display notable patterns across the fixed-effects specifications. In the Innovation equation, cash flow, growth, and firm size are positively associated with the Innovation proxy, with estimated coefficients of 0.204, 2.445, and 0.552, respectively. These results indicate that within-firm changes in internal financing capacity, expansion, and organizational scale are associated with variation in observable innovation-related investment and intangible capability. Because these variables are measured on different scales, the magnitudes of their coefficients should not be compared directly. In the ROA, ROE, and Tobin's Q equations, the corresponding control-variable coefficients are comparatively modest and do not display the same pattern observed in the Innovation equation. These variables are included primarily to account for observable time-varying firm characteristics rather than as focal explanatory variables, and their coefficients should therefore be interpreted as conditional associations rather than causal effects. Overall, the results indicate that firm-level characteristics remain relevant when assessing the associations among FinTech-related disclosure, Innovation, and firm outcomes.

Table 10. Temporal-ordering and reverse-prediction robustness tests.

Test	Estimate	Clustered SE	p-value	Firm FE	Year FE
Panel A: One-year-lagged FinTech					
FinTech(t−1) → Innovation(t)	−0.158	1.074	0.883	Yes	Yes
FinTech(t−1) → ROA(t)	0.026	0.170	0.880	Yes	Yes
FinTech(t−1) → ROE(t)	−0.230	0.112	0.046	Yes	Yes
FinTech(t−1) → Tobin's Q(t)	−0.101	0.189	0.597	Yes	Yes
Panel B: Reverse-prediction tests					
ROA(t−1) → FinTech(t)	0.017	0.075	0.821	Yes	Yes
ROE(t−1) → FinTech(t)	0.115	0.071	0.114	Yes	Yes
Tobin's Q(t−1) → FinTech(t)	0.020	0.044	0.658	Yes	Yes

Note: All specifications include firm and year fixed effects. Standard errors are clustered at the firm level. The reduction from 234 to 195 observations reflects the loss of the first annual observation for each of the 39 firms when constructing one-year-lagged variables.

The reverse-prediction specifications show that lagged ROA, ROE, and Tobin's Q are not statistically significantly associated with subsequent FinTech-related disclosure. These results provide no evidence of reverse predictive associations within the specific one-year-lagged specifications examined. However, the absence of statistically significant reverse-prediction coefficients should not be interpreted as ruling out reverse causality or resolving endogeneity concerns. These tests do not account for potential omitted time-varying variables, simultaneity, or measurement error, and they do not provide exogenous variation in FinTech-related disclosure. Accordingly, the reverse-prediction results are interpreted only as temporal-ordering diagnostics and not as evidence of causal direction.

5. Discussion

5.1. Discussion of main findings

In this study, we examined the relationships between FinTech-related disclosure and firm outcomes in the Saudi financial sector, with Innovation considered as a potential intermediary pathway. The findings differ in important respects across the two empirical approaches. PLS-SEM identifies positive associations between FinTech-related disclosure, Innovation, and firm outcomes, as well as significant indirect Innovation-related associations. The more conservative two-way fixed-effects estimates provide stronger support for the contemporaneous FinTech-related relationships: FinTech-related disclosure remains positively associated with Innovation, ROA, ROE, and Tobin's Q after controlling for time-invariant firm heterogeneity and common year effects. However, the Innovation-to-outcome coefficients are not statistically significant in the fixed-effects specifications. Accordingly, greater interpretive weight is placed on the fixed-effects evidence, and the findings are interpreted as providing stronger support for contemporaneous associations between FinTech-related disclosure and firm outcomes than for a robust Innovation-related pathway. The mediation evidence is therefore regarded as specification-sensitive rather than as a uniformly supported finding.

The lack of persistence in the one-year-lagged results warrants particular attention. While FinTech-related disclosure is positively associated with firm outcomes contemporaneously, lagged FinTech-related disclosure is not significantly associated with subsequent Innovation, ROA, or Tobin's Q, and its association with subsequent ROE is negative and statistically significant. Several factors may plausibly contribute to this divergence. FinTech-related investments and organizational adjustments may generate contemporaneous operational benefits while involving implementation, integration, training, and restructuring costs that can affect subsequent profitability. In addition, the timing of economic returns from digital transformation may not correspond to a uniform one-year horizon, particularly when institutions differ in implementation speed and organizational readiness. The disclosure-based FINTECH proxy may also capture contemporaneous digital transformation activity more effectively than the timing at which its economic consequences materialize. These explanations remain plausible interpretations rather than mechanisms directly tested in this study.

Importantly, the lagged evidence changes the strength of the conclusions that can be drawn from the contemporaneous results. The absence of consistent positive lagged relationships, together with the negative lagged association with ROE, indicates that the contemporaneous findings should not be interpreted as demonstrating persistent performance improvements. They may instead reflect relationships that arise concurrently during periods of digital transformation. The present evidence therefore supports contemporaneous associations more strongly than persistent intertemporal effects and does not establish that greater FinTech-related disclosure causes subsequent improvements in firm outcomes.

The divergence between the PLS-SEM and fixed-effects results also warrants methodological consideration. The two approaches rely on different sources of variation and address different empirical questions. PLS-SEM evaluates the hypothesized multivariate structural associations using the variation represented in the pooled firm-year data, whereas the two-way fixed-effects models identify associations primarily from changes within the same institution over time after removing time-invariant firm characteristics and common year effects. Consequently, relationships that are evident in the structural model may weaken when the analysis is restricted to within-firm variation. This distinction may be particularly relevant for the Innovation proxy, which reflects accounting-based innovation-related investment and accumulated intangible capability and may change relatively gradually over time. Limited within-firm variation in this measure may contribute to the weaker Innovation-to-outcome coefficients in the fixed-effects specifications. In addition, measurement error in accounting-based and disclosure-based proxies may become more consequential when estimation relies on within-firm changes. These considerations provide plausible explanations for the divergence across specifications, although this analysis does not directly test which explanation accounts for the difference.

The relatively limited cross-sectional and temporal dimensions of the sample should also be considered when interpreting this divergence across estimation approaches. Although the balanced panel contains 234 firm-year observations, the fixed-effects estimates are based on only 39 institutions observed over six years. This relatively limited cross-sectional and temporal structure may constrain the precision with which longitudinal relationships are estimated and may partly contribute to the weaker Innovation-related evidence under fixed effects. However, the divergence cannot be attributed to sample structure alone, as the two approaches differ in their estimation objectives, sources of identifying variation, and treatment of firm heterogeneity. The contrasting results are therefore interpreted as evidence that the Innovation-related relationships are sensitive to model specification and sample structure, rather than as evidence that either estimation approach is inherently inappropriate.

The results for the firm-level controls provide additional context for interpreting the focal relationships. In the PLS-SEM specification, the Firm Characteristics component, comprising size, growth, and cash flow, is positively associated with both Financial Performance and Market Valuation. In the fixed-effects models, these controls are entered separately, and their most notable positive associations are observed in the Innovation equation, whereas their coefficients in the ROA, ROE, and Tobin's Q equations are comparatively modest. This difference reflects, in part, the distinct specification of the controls across the two empirical approaches: PLS-SEM represents them jointly within the Firm Characteristics component, whereas the fixed-effects models estimate their individual associations using within-firm variation over time. Accordingly, the control-variable results reinforce the importance of accounting for observable firm-level heterogeneity, but they are not interpreted as independent causal determinants of firm outcomes.

Accordingly, the mixed findings are treated as substantively informative rather than as a simple robustness failure: The evidence is comparatively stronger for the contemporaneous FinTech-related associations that remain significant under fixed effects, whereas the Innovation-related pathway is more dependent on model specification.

The positive contemporaneous association between FinTech-related disclosure and financial performance is consistent with prior research emphasizing the role of digital financial technologies in improving process efficiency, reducing transaction costs, and enhancing service delivery in financial institutions (Gomber et al., 2018; Thakor, 2020). Similar associations have been documented in banking and financial services, where automation and data-driven decision-making may contribute to improved operational and financial outcomes (Chen et al., 2019). Consistent with this literature, the findings indicate that greater FinTech-related disclosure is contemporaneously associated with stronger firm outcomes within the study period, while the lagged evidence cautions against extending this association to subsequent performance.

In the Saudi context, these findings are particularly relevant given the expansion of digital banking platforms and FinTech-enabled services under Vision 2030. The institutional and regulatory environment has supported the development of digital financial services, providing a context in which financial institutions have increasingly incorporated FinTech-related technologies into their operations. The observed positive contemporaneous relationships are therefore consistent with the broader digital transformation of the Saudi financial sector.

5.2. FinTech adoption and innovation capability

The results indicate a significant positive contemporaneous association between FinTech-related disclosure and Innovation across both empirical approaches. PLS-SEM identifies a positive relationship between the two variables, while the two-way fixed-effects specification shows that this association remains statistically significant when estimation relies on within-firm variation and controls for time-invariant firm heterogeneity and common year effects. The consistency of this relationship across the two approaches provides stronger support for the contemporaneous association between greater FinTech-related disclosure and higher levels of observable innovation-related investment and intangible capability within financial institutions.

This finding is consistent with innovation-oriented perspectives emphasizing the complementarities between digital technologies and firm capabilities (Lee & Shin, 2018; Vives, 2019).

Digital technologies may facilitate organizational learning, information processing, experimentation, and knowledge recombination, thereby creating conditions that support innovation-related activities.

However, the one-year-lagged analysis does not show a statistically significant association between prior FinTech-related disclosure and subsequent Innovation. This lack of persistence indicates that the contemporaneous association should not be interpreted as evidence that greater FinTech-related disclosure leads to subsequent increases in innovation-related investment or intangible capability. Instead, FinTech-related disclosure and innovation-related activities may develop concurrently as part of the broader digital transformation of financial institutions. Moreover, the lagged specification does not constitute a causal identification strategy and cannot rule out omitted time-varying factors, simultaneity, or measurement error. Accordingly, the evidence supports a contemporaneous association between FinTech-related disclosure and Innovation-related investment and intangible capability but does not establish the direction or causal nature of this relationship.

5.3. Innovation as a potential intermediary pathway

The evidence regarding the intermediary role of Innovation differs across the two empirical approaches. PLS-SEM identifies statistically significant indirect associations between FinTech adoption and firm outcomes through Innovation, suggesting a potential Innovation-related pathway within the structural model. This pattern is consistent with resource-based perspectives, which emphasize that technological resources may be associated with firm outcomes when combined with complementary organizational and innovation capabilities (Rosenbusch et al., 2011; Thakor, 2020).

However, the more conservative two-way fixed-effects estimates do not provide equivalent support for this pathway. Although FinTech-related disclosure remains positively associated with Innovation, the coefficients of Innovation are not statistically significant in the ROA, ROE, and Tobin's Q equations. Thus, the Innovation-to-outcome associations identified by PLS-SEM are not reproduced when estimation relies on within-firm variation and controls for time-invariant firm heterogeneity and common year effects. As discussed in Section 5.1, this divergence may reflect the different sources of variation used by the two empirical approaches, particularly given the potentially gradual within-firm evolution of the accounting-based Innovation proxy. Accordingly, the difference across specifications is treated as substantively informative, and greater interpretive weight is placed on the fixed-effects evidence when assessing the robustness of the proposed intermediary pathway.

Accordingly, the findings do not provide uniformly robust evidence that Innovation mediates the relationship between FinTech-related disclosure and firm outcomes. Rather, the significant indirect associations identified by PLS-SEM should be interpreted as specification-sensitive evidence of a potential Innovation-related pathway. These indirect associations represent statistical relationships within the structural model and should not be interpreted as evidence of causal mediation. Neither the PLS-SEM specification nor the fixed-effects and temporal-ordering analyses provide an identification strategy capable of ruling out omitted time-varying factors, simultaneity, or measurement error. Further longitudinal research using alternative measures of innovation and stronger identification strategies is therefore needed to determine whether the proposed pathway persists over time and whether a causal mechanism can be established.

5.4. Market valuation

The positive contemporaneous association between FinTech-related disclosure and Tobin's Q should be interpreted cautiously in the context of financial institutions. Unlike non-financial firms, banks and other financial institutions have distinctive balance-sheet structures in which financial assets and liabilities constitute a substantial part of their operations, and the asset-based approximation of Tobin's Q may therefore have a different economic interpretation. Accordingly, the positive coefficient should be understood as indicating a relative contemporaneous association between greater FinTech-related disclosure and the market-valuation indicator within the study sample, rather than as evidence that FinTech-related disclosure increases conventional growth opportunities, generates excess market value, or causes higher firm valuation.

The comparatively weaker association with the Tobin's Q-based market-valuation indicator may reflect the different ways in which financial markets evaluate digital transformation initiatives. Investors may consider not only potential operational benefits but also uncertainty related to implementation costs, regulatory developments, technological obsolescence, and competitive dynamics (Villalonga, 2004; Vives, 2019). Consequently, the contemporaneous association between FinTech-related disclosure and Tobin's Q-based market-valuation indicator may differ from its associations with accounting-based measures of firm performance. Given the measurement considerations noted above, however, this difference should not be interpreted as direct evidence of a specific investor response to FinTech-related activities.

The role of Innovation in this market-valuation relationship should also be interpreted cautiously. PLS-SEM identifies a significant Innovation-related pathway to Tobin's Q, whereas the more conservative two-way fixed-effects specification does not yield a statistically significant Innovation coefficient in the Tobin's Q equation. Given the longitudinal structure of the data, greater interpretive weight is placed on the fixed-effects evidence when assessing the robustness of this relationship. Moreover, one-year-lagged FinTech-related disclosure is not significantly associated with subsequent Tobin's Q. This lack of persistence is consistent with the broader temporal pattern observed for the other outcomes and indicates that the positive contemporaneous association with the market-valuation indicator does not extend reliably to the following year. Taken together, these results provide stronger support for a contemporaneous within-sample association between FinTech-related disclosure and the Tobin's Q-based market-valuation indicator than for either a robust Innovation-related pathway or a persistent intertemporal relationship. Accordingly, the findings should not be interpreted as establishing a causal effect of FinTech-related disclosure on market valuation.

5.5. Theoretical implications

This study contributes to the literature on FinTech, innovation, and firm performance in several ways. First, the findings are consistent with the resource-based view by showing that FinTech-related disclosure is positively associated with firm outcomes and may reflect the relevance of technological resources within financial institutions. The persistence of these contemporaneous associations in the two-way fixed-effects models provides comparatively stronger evidence that they are not solely attributable to time-invariant firm characteristics or common year-specific effects. However, the mixed evidence from the one-year-lagged specifications indicates that these contemporaneous relationships should not be interpreted as establishing persistent or causal effects on subsequent firm outcomes.

Second, the study contributes to innovation-based perspectives by examining Innovation as a potential intermediary pathway through which FinTech-related disclosure may be associated with firm outcomes. PLS-SEM identifies significant indirect Innovation-related associations, whereas the more conservative two-way fixed-effects estimates do not provide equivalent support for Innovation-to-outcome relationships. This divergence is theoretically informative because it suggests that the relevance of Innovation to the FinTech-related disclosure–outcome relationship depends partly on the empirical specification and the source of variation being examined. Given that the fixed-effects models rely on within-firm changes over time, greater interpretive weight is placed on these estimates when assessing the robustness of the proposed intermediary pathway. The findings therefore support a conditional interpretation of Innovation as a plausible complementary pathway rather than a uniformly supported or causal mechanism linking FinTech-related disclosure to firm outcomes.

Finally, by focusing on an emerging financial market, the study responds to calls for greater contextual diversity in FinTech research (Haddad & Hornuf, 2019; Gomber et al., 2018). The Saudi financial sector provides a relevant setting characterized by rapid digital transformation and institutional development. The findings extend the empirical literature by showing that contemporaneous relationships between FinTech-related disclosure, Innovation-related investment and intangible capability, and firm outcomes are also evident in an emerging-market context. Furthermore, the differences across empirical specifications highlight the importance of accounting for model specification, the source of empirical variation, and temporal ordering when interpreting these relationships.

5.6. Managerial and policy implications

From a managerial perspective, the findings suggest that FinTech-related activities should be evaluated in relation to observable firm outcomes rather than assumed to generate performance improvements automatically. The positive contemporaneous associations with financial performance and market valuation indicate that FinTech-related disclosure is relevant to firms' current operating and financial context; however, the absence of consistent positive one-year-lagged relationships cautions against interpreting these associations as evidence of sustained performance benefits. Managers may therefore consider monitoring the realized outcomes of FinTech-related initiatives over multiple periods and evaluating whether observed improvements persist beyond the period in which digital transformation activities are undertaken or reported. The specification-sensitive evidence regarding Innovation further suggests that its role as an intermediary pathway should not be treated as established. These implications are intended as considerations for managerial evaluation rather than as prescriptive recommendations, given the non-causal nature of the evidence.

From a policy perspective, the findings provide contextual evidence relevant to the ongoing digital transformation of the Saudi financial sector but do not identify the effects of specific regulatory interventions. The positive contemporaneous associations documented in the study, together with the absence of consistent positive one-year-ahead relationships, suggest the value of continued longitudinal monitoring of FinTech-related developments and firm outcomes. For regulators and policymakers, improving the consistency and comparability of corporate disclosure concerning FinTech-related activities could facilitate more systematic assessment of how digital transformation evolves across financial institutions and over time. However, the findings do not provide a basis for

recommending specific regulatory arrangements or for concluding that particular policy interventions would improve firm performance. The policy implications should therefore be understood as directions for monitoring, disclosure, and future evidence gathering rather than as causal policy prescriptions.

5.7. Summary

Overall, the findings indicate that FinTech-related disclosure is positively associated with firm outcomes in the Saudi financial sector, with the strongest evidence relating to contemporaneous relationships. Innovation emerges as a plausible intermediary pathway within the PLS-SEM specification, although the strength of this relationship varies across empirical specifications. Taken together, the results suggest that the relationship between FinTech adoption and firm outcomes should be understood as context- and specification-sensitive rather than as evidence of an automatic or persistent causal effect. These findings reinforce the importance of considering innovation-related capabilities and temporal dynamics when evaluating the implications of FinTech adoption in financial institutions.

6. Conclusions and Implications

Using PLS-SEM together with two-way fixed-effects panel estimation, this study provides evidence of positive contemporaneous relationships between FinTech-related disclosure and Innovation-related investment and intangible capability, financial performance, and the Tobin's Q-based market-valuation indicator. These relationships are identified by PLS-SEM and remain evident in the more conservative fixed-effects specifications after accounting for time-invariant firm heterogeneity and common year effects. Given the distinctive balance-sheet structure of financial institutions and the asset-based approximation of Tobin's Q employed in this study, the market-valuation result should be interpreted as a relative within-sample association rather than as evidence of conventional growth opportunities, excess market value, or a direct investor response to FinTech-related activities.

The evidence regarding the Innovation-related intermediary pathway and the persistence of the FinTech-related relationships is less robust across empirical specifications and time horizons. Although PLS-SEM identifies significant indirect associations through Innovation, the Innovation-to-outcome coefficients are not statistically significant in the two-way fixed-effects specifications. Moreover, the one-year-lagged analyses do not reproduce the positive contemporaneous pattern: Lagged FinTech-related disclosure is not significantly associated with subsequent Innovation, ROA, or Tobin's Q, while its association with subsequent ROE is negative and statistically significant. These findings indicate that the observed positive relationships are primarily contemporaneous and do not provide evidence of persistent positive associations over a one-year horizon. Accordingly, greater interpretive weight is placed on the fixed-effects and temporal-ordering evidence when assessing the robustness of the findings, and the results should be interpreted as associations rather than as evidence of causal effects.

The study contributes to the FinTech literature by providing firm-level evidence from the Saudi financial sector, an emerging-market setting characterized by rapid digital and institutional transformation. It further contributes by examining Innovation as a potential intermediary pathway rather than focusing exclusively on the direct association between FinTech-related disclosure and firm outcomes. The findings suggest that the relevance of Innovation to the FinTech-related disclosure–outcome relationship is sensitive to empirical specification and to the source of variation used for estimation. In particular, the weaker Innovation-to-outcome relationships in the fixed-effects models indicate that the indirect pathway

identified by PLS-SEM is less evident when estimation relies on within-firm changes over time. This divergence is therefore treated as an informative empirical finding rather than as a secondary robustness qualification. It also reinforces the importance of distinguishing accounting-based financial performance and the Tobin's Q-based market-valuation indicator when evaluating these associations, particularly given the measurement considerations associated with applying Tobin's Q to financial institutions.

From a practical and policy perspective, the findings support a cautious approach to interpreting the implications of FinTech-related activities. For managers, the positive contemporaneous associations suggest the relevance of monitoring FinTech-related initiatives alongside observable firm outcomes, while the lack of consistent positive one-year-lagged relationships cautions against assuming that such associations translate into sustained performance improvements. For regulators and policymakers, the findings highlight the value of consistent FinTech-related disclosure and continued longitudinal monitoring of digital transformation and firm outcomes. However, because we do not establish causal effects or evaluate specific regulatory interventions, these implications should be viewed as considerations for managerial evaluation, monitoring, and future evidence gathering rather than as prescriptive recommendations regarding particular managerial practices or regulatory policies.

The findings should nevertheless be interpreted in light of several limitations. Although the fixed-effects and temporal-ordering analyses account for time-invariant firm heterogeneity, common year effects, and the sequencing of the observed relationships, they do not eliminate potential endogeneity arising from omitted time-varying factors, simultaneity, or measurement error. The reverse-prediction and one-year-lagged specifications should therefore be viewed as diagnostic analyses rather than causal identification strategies. In addition, the absence of consistent positive relationships in the one-year-lagged specifications limits conclusions regarding persistent intertemporal effects. The Innovation measure is an accounting-based proxy for observable innovation-related investment and intangible capability and therefore may not capture all dimensions of innovation activity or realized innovation output.

The sample structure also warrants caution. The analysis is based on 39 listed Saudi financial institutions observed over the 2018–2023 period. Although the balanced panel provides 234 firm-year observations, the cross-sectional base remains relatively limited, which may constrain the precision of longitudinal estimates, particularly when identification depends on within-firm variation over a six-year period. Moreover, the sample is drawn from a single national and sectoral setting. The findings should therefore be interpreted primarily within the context of listed financial institutions in Saudi Arabia and should not be assumed to generalize directly to unlisted financial institutions, standalone FinTech firms, non-financial sectors, or institutions operating under different regulatory and institutional environments.

Researchers could address these limitations by examining larger samples and longer observation periods, employing alternative and more direct measures of FinTech adoption and Innovation, and using research designs that provide stronger causal identification. Cross-country and cross-sector analyses could further assess whether the contemporaneous FinTech-related associations and the specification-sensitive Innovation-related relationships documented in this study persist across institutional and regulatory environments. Researchers could also examine heterogeneity across financial subsectors and different stages of digital transformation.

Author Contributions

Conceptualization, A.A. and B.J.; methodology, B.J.; software, B.J.; validation, A.A. and B.J.; formal analysis, B.J.; investigation, A.A.; resources, A.A.; data curation, A.A.; writing original draft preparation, B.J.; writing review and editing, A.A. and B.J.; visualization, B.J.; supervision, B.J.; project administration, B.J.; funding acquisition, B.J.

All authors have read and agreed to the published version of the manuscript.

Use of AI tools declaration

The authors used ChatGPT (OpenAI) for assistance with academic language, grammatical refinement, and suggestions for improving manuscript structure and clarity. The authors reviewed the outputs and incorporated suggestions where appropriate.

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Conflict of interest

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Not applicable.

Data availability statement

The data supporting the findings of this study are derived from publicly available sources. Financial data were obtained from the audited annual reports of financial institutions listed on the Saudi Exchange (Tadawul) and from the Tadawul disclosure platform. Data related to FinTech adoption were collected from FinTech Saudi publications, the Saudi Central Bank (SAMA), and the Saudi Payments Network (SPN).

The processed dataset and analytical procedures used in this study are available from the corresponding author upon reasonable request.

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