

## Does ESG scores moderate the impact of FinTech on investment efficiency? Insights from firms in the MENA region

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### ABSTRACT

This paper explores the efficacy of ESG performance in high-tech adoption and investment efficiency in the Middle East and North African (MENA) region. The focus on the MENA region is particularly relevant given the rapid expansion of digital ecosystems in the area, combined with heterogeneous institutional frameworks, where the interaction between sustainability practices and technology adoption remains insufficiently studied. The study seeks to investigate whether ESG scores strengthen the effect of FinTech adoption on both capital allocation and firm performance. Modeling a panel of firm-year observations ( $n = 4417$ ) for the years 2010–2024, OLS regression, two-stage Heckman models, and 2SLS estimation are used to examine main effects and moderators. Findings show that FinTech adoption positively influences investment efficiency and this effect is stronger among firms with high ESG scores, and ESG scores are a determinant of the efficient investment allocation. The results are also robust to alternative specifications of the model. Theoretically, the study extends our understanding of ESG performance as related to digital transformation in nascent institutional environments. As a matter of practical policy, it offers direction for policymakers and managers in the MENA region to incorporate sustainability within technology adoption policies.

#### Key Findings:

- FinTech adoption improves investment efficiency.
  - The positive effect is stronger for firms with higher ESG scores, indicating ESG as a strategic facilitator for digital transformation.
  - ESG scores are independently linked to efficient capital allocation.
  - Results are robust across various econometric models.
- Implications:
- ESG can be leveraged to enhance digital and FinTech adoption strategies.

Policymakers and managers in MENA countries can align

sustainability initiatives with technological innovation to improve corporate performance.

### Introduction

Governance and financial systems in the MENA region are evolving rapidly as governments implement structural reforms, modernize regulatory frameworks, and encourage growth driven by innovation (World Bank, 2022; OECD, 2021). However, despite such ambitious policies, the region still confronts serious challenges such as financial opacity; uneven digitalization and unequal access to digital technology and services; fragmented governance standards and less effective capital allocation (Arab Monetary Fund 2020). Policy implications of these

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challenges are substantial, as investments may be hindered by issues such as information asymmetries, suspect (or feeble) disclosure, and poor monitoring, all of which reduce investment efficiency.

Beyond firm-level mechanisms, recent studies also emphasize the role of information transparency and stakeholder interaction in shaping sustainable outcomes in digital environments, including aspects such as public participation and information dependency (e.g., Zhao et al., 2024; Xue et al., 2025). These perspectives further highlight the importance of credible information ecosystems, which are likewise central to ESG disclosure and FinTech-enabled financial decision-making.

To address these challenges, financial technology (FinTech) such as digital payment services, alternative finance technologies and data-driven decision-making systems has been suggested as a response to these inefficiencies. However, FinTech adoption alone may not fully overcome structural barriers as digital uptake differs widely across countries and firms. In particular, the lack of standardized disclosure definitions, as well as inconsistent enforcement of reporting regulation and fragmented ESG standards all result in "mixed rules" that compromise FinTech's ability to improve transparency and capital allocation.

Yet much of the research from advanced economies assumes that investment quality is automatically enhanced by digitalization; MENA, with its mixed state-led markets and varying governance quality and firm readiness for technology adoption. Revealing the interplay between institutional conditions and firm-level aspects is therefore an essential point for the development of successful policy intervention, better corporate disclosure and investment efficiency in emerging markets.

Within this setting, the objective of the present study is to explore whether and how ESG performance mediates the effect of FinTech adoption on investment efficiency in MENA firms. The study posits that credible, consistently reported, and mainstreamed ESG indicators improve transparency, reduce information asymmetry and increase financial dependability. In low-regulated settings, positive ESG activity can provide some counterbalance to institutional gaps and help FinTech tools function better. In contrast, firms with low ESG performance may not benefit from better disclosure quality if their governance is poor and investor risk aversion is high.

Within this context, the MENA region constitutes an especially suitable and policy-sensitive case to examine. Gulf economies are making far more progress in ESG and in the use of digital finance, while countries in North Africa and the Levant remain behind other parts of the Mena region when it comes to regulatory harmonization and market transparency. Exploring these differences has potential implications not only for Mediterranean and MENA policy makers, but in other developing and emerging markets that exhibit varying stages of technology and regulation.

From a theoretical perspective, this contribution fulfills the calls for a more integrated approach by connecting FinTech adoption to ESG performance and investment efficiency in an institutionally heterogeneous and partly institutionalized setting. In doing so it challenges the overarching perception, common in Western-focused literature, that FinTech always enhances investing (Donders, 2019). In practical terms, the study also provides managerial and policy implications, highlighting the role of ESG reporting standards, regulatory compliance, and policies that foster synergies between digital innovation and responsible corporate behavior.

The rest of the paper proceeds as follows: Section 2 provides a review of literature and develops the theoretical framework, Section 3 discusses empirical methodology, Section 4 presents results and robustness checks while Section 5 concludes with policy implications and managerial recommendations.

## Review of relevant literature

### *Foundational concepts and theoretical framework*

The study explores ESG performance mediation on FinTech adoption–corporate investment efficiency relationship in MENA region. The analysis draws on a metatheoretical framework comprising stakeholder theory, resource-based view (RBV), agency theory, institutional theory, and information asymmetry to provide solid theoretical grounding. Building on this view of digital transformation, this study conceptualizes ESG performance as a strategic and institutional mechanism through which the impact of digital transformation mediates firm-level investment outcomes — especially in emerging and heterogeneous institutional contexts where firms operate.

Grounded in stakeholder theory (Freeman, 1984), firms with stronger ESG commitments are more inclined to legitimize and effectively implement FinTech adoption within their organizational processes. ESG disclosure enhances transparency, reduces stakeholder mistrust of stakeholder's skepticism, and strengthens corporate credibility, thereby facilitating acceptance and effective of digital financial systems. However, prior literature has often treated the relationship between transparency and financial results as linear, overlooking the importance of contextual dependencies. In line with recent research on digital innovation and sustainability (e.g., Xue et al., 2025), these insights suggest that access to digital technologies alone is insufficient to lead directly to generating efficiency gains, as their effectiveness depends largely on governance quality and stakeholder alignment. Furthermore, other recent studies have emphasized the significance of public participation, public complaints, and social accountability in driving corporate governance and sustainability practices (Sun et al., 2024). In this context, ESG practices contribute to improving the firm's information environment and act as signaling mechanisms that enhance investor confidence and access to capital. Thus, ESG performance could be conceptualized as a mediating mechanism that strengthens the impact of FinTech adoption on corporate investment efficiency.

From the RBV perspective (Barney, 1991), both ESG capabilities and FinTech adoption can be understood as strategic, firm-specific resources that contribute to competitive advantages. ESG practices, including sustainability reporting systems, governance structures, and risk management frameworks, are considered intangible assets that enhance organizational legitimacy and resilience. At the same time, FinTech technologies such as big data analytics and digital payment platforms improve operational efficiency and reduce transaction costs. Importantly, recent research suggest that digital innovation and sustainability capabilities are not independent, but mutually reinforcing (Wang et al., 2025; Zhao et al., 2024). For example, it has been found that digital empowerment may promote the transition to a low-carbon economy and improve the efficiency of resource allocation (Sun et al., 2024; Di et al., 2024a), while examining green and circular economies emphasizes the complementary nature between digitalization and sustainability (Di et al., 2023; Di et al., 2024b). Within this framework, ESG performance can be interpreted as a complementary capability that effectively enhances the value-creation potential of FinTech adoption. However, despite growing attention to this interaction, the literature still provides limited evidence on how these complementarities operate in emerging and institutionally heterogeneous markets.

This relationship can be further explained through agency theory, particularly in the context of the MENA region, where ownership concentration and family control are prevalent. These structural characteristics tend to exacerbate principal–agent conflicts and increase information asymmetries between managers and investors. Although FinTech technologies can enhance monitoring through real-time data

availability and advanced analytics, their applicability may be constrained in environments characterized by weak governance structures. In such contexts, ESG performance plays a critical role by improving disclosure quality, strengthening governance mechanisms, and enhancing accountability. By mitigating agency conflicts and reducing information asymmetries, ESG practices enable firms to better leverage FinTech tools for more efficient investment decisions. Empirical evidence supports this argument, showing that ESG engagement contributes to lowering agency costs and improving resource allocation. In addition, recent evidence on carbon information disclosure highlights how transparency requirements and governance incentives can discipline managerial behavior and align corporate decisions with sustainability goals (Sun et al., 2025). Accordingly, ESG can be conceptualized as a mediating mechanism that enhances the effectiveness of FinTech adoption in improving investment efficiency.

Institutional theory (DiMaggio and Powell, 1983) provides an additional perspective by emphasizing the role of regulatory, normative, and cognitive pressures in shaping corporate behavior. In the MENA region, these forces create a fragmented institutional landscape, characterized by significant heterogeneity in the development of digital infrastructure and the standardization of ESG practices. Although governments have implemented reforms to promote sustainability and financial innovations, persistent challenges remain, including weak enforcement, insufficient harmonization of ESG standards, and gaps in digital infrastructure (World Bank, 2022; OECD, 2021). These institutional constraints shape both the incentives and the capacity of firms to adopt and effectively utilize FinTech solutions, particularly in contexts where institutional coordination and regional policy alignment remain limited (Di et al., 2024c). Recent interdisciplinary research also highlights the growing importance of broader governance dynamics, such as public participation, digital governance, and social accountability, in shaping corporate sustainability practices (Cai et al., 2025a; Cai et al., 2025b). These insights suggest that ESG adoption should not be viewed solely as a compliance response but as a strategic adaptation to evolving institutional and societal expectations. Within this context, ESG performance can enhance firm's legitimacy and reduce institutional uncertainty, thereby facilitating the effective exploitation of FinTech innovations and ultimately improving investment efficiency.

From the perspective of the information asymmetry theory (Akerlof, 1970), the mechanism proposed is also well-founded, as transparency plays a key role in reducing market inefficiencies. According to this theory, ESG disclosure enhances the credibility, comparability, and reliability of corporate information, thereby enabling investors to more effectively assess investment opportunities. These benefits are further amplified in FinTech-enabled environments, where digital tools facilitate processing and dissemination of information. Although previous literature highlights the role of digital technologies in reducing information friction, it often overlooks the importance of underlying governance quality and disclosure standards. In this regard, recent studies on digital transparency and information environments (Zhao et al., 2024; Cai et al., 2025a) emphasize that information quality and user trust are critical determinants of the effectiveness of digital systems. Accordingly, ESG performance may mitigate information asymmetries by improving disclosure quality and strengthening investor confidence, thereby enhancing the effectiveness of FinTech in supporting more efficient capital allocation.

Empirical evidence supporting these theoretical linkages remains partial and context dependent. While most of prior studies show that higher ESG performance is associated with lower firm risk, improved financial performance, and more efficient resource allocation, and that FinTech adoption enhances information efficiency and reduces transaction costs, these effects are not universally observed. Their impact is often contingent on governance quality and institutional capacity. Research on digital innovation, sustainable development, and financial market dynamics highlights the persistent challenges associated with integrating technological and sustainability dimensions in emerging

economies (e.g., Pandey, 2025a, 2025b, 2025c). These insights suggest that the benefits of ESG and FinTech may be constrained in environments characterized by institutional fragmentation and weak regulatory enforcement.

Despite these initiatives, literature remains fragmented and mostly focused on advanced economies with well-established institutional frameworks. Moreover, limited empirical evidence exists on mediating role of ESG performance in the relationship between FinTech adoption and investment efficiency, especially in emerging regions such as MENA. It is important to note that most of previous studies have been based on the implicit assumption that the effects of digital transformation and sustainability practices are uniformly positive, often overlooking the role of institutional heterogeneity and governance constraints.

Considering these gaps, this study introduces a theoretically integrated and context-sensitive framework that postulates ESG performance as a mediating mechanism in the relationship between FinTech adoption and corporate investment efficiency. Study contributes to literature in several ways. First, it advances a multi-theoretical perspective by integrating insights from stakeholder theory, RBV, agency theory, institutional theory, and information asymmetry theory. Second, it re-conceptualizes ESG and FinTech as complementary capabilities. Third, it explicitly incorporates institutional heterogeneity, providing a better understanding of how contextual factors influence these relationships. Finally, it provides empirical evidence from the under-explored MENA region, where digital and sustainability transitions are evolving under uneven regulatory conditions.

#### *Study framework and hypothesis design*

The study tests how FinTech adoption influences corporate investment efficiency in the MENA region, and explores ESG performance both as an independent determinant and as a moderating factor in this relationship. Investment efficiency refers to the extent to which a firm allocates capital appropriately, avoiding systematic over- or underinvestment. FinTech adoption reflects the extent to which firms implement digital financial technologies, such as blockchain-based reporting systems, digital payment platforms, algorithm-based risk assessment, and data analytics, within their financial and managerial processes (Lv & Xiong, 2019; Huang, 2022). ESG performance is defined as the overall scoring of environmental, social and governance practices, capturing aspects such as transparency, risk management, and governance quality.

The theoretical model considers FinTech adoption as the explanatory variable, investment efficiency as the dependent variable and ESG variables both as a direct predictor and as a moderating factor. This dual role is theoretically grounded: ESG practices can directly improve disclosure quality and governance, while also strengthening the effect of FinTech adoption on capital allocation, particularly in emerging institutional environments where regulatory enforcement remains uneven (Jiang et al., 2025).

The framework is based on four theoretical perspectives. Stakeholder theory emphasizes ESG's importance in fostering trust of investors and regulators. Agency theory highlights ESG's contribution to reducing information asymmetry and agency costs, while RBV places them as complementary strategic resources for FinTech. Institutional theory, in turn, portrays ESG as a legitimacy signal that can enhance the effectiveness of FinTech in contexts characterized by weak or heterogeneous governance structures. Taken together, these theories support the proposed direct and moderate effects.

#### *FinTech adoption and corporate investment efficiency*

The FinTech adoption is now widely accepted as a prominent determinant of corporate investment efficiency. By incorporating technologies such as electronic payment systems, blockchain-based reporting, predictive analytics and algorithmic risk assessment, firms can reduce transaction cost, enhance transparency, and accelerate capital allocation processes (Lv & Xiong, 2019; Huang, 2022; Dhiaf et al.,

2024) This mechanism may be particularly relevant in the MENA region, where fragmented capital markets and uneven institutional enforcement persists. In such contexts, FinTech adoption can help overcome structural inefficiencies and reduce mismatches between investment decisions and stakeholder expectations (Qi et al., 2024; Lin et al., 2023).

The relationship between FinTech adoption and investment efficiency can be understood through multiple theoretical lenses. Prior research suggests that digital financial technologies enhance transparency, reduce information asymmetries, and improve decision-making processes, thereby supporting more efficient capital allocation (Siddik et al., 2023). From a strategic perspective, FinTech can also be viewed as an organizational capability that interacts with other firm resources to improve performance, while its effectiveness depends on the institutional and regulatory environment in which firms operate (Lv & Xiong, 2019; Jiang et al., 2025; Liu, 2024).

In the empirical analysis, FinTech adoption is measured using the logarithm of the number of FinTech firms at the country level. This indicator also illustrates the maturity and availability of the national digital financial ecosystem, reflecting the structural and infrastructural conditions that shape the benefits of FinTech adoption. Such a proxy is particularly useful in the MENA context where firm-level measures of digital innovation are often limited. Prior studies show that firms operating in countries with more developed FinTech environments tend to incur lower transaction costs and make faster investment decisions that better align with investor expectations (Dhiyf et al., 2024).

Besides, the application of FinTech can create long-term value for corporations by increasing operation efficiency, promoting data-driven decision making and supporting sustainable investment (Wang et al., 2024; Du et al., 2023). Digitalization enhances risk management, mitigates information asymmetry, and enables more efficient capital allocation, yet the effects are contingent on firm-specific capabilities and institutional environment (Lee et al., 2021; Tang et al., 2023).

Drawing upon these theoretical and empirical rationales, the following Hypothesis is first developed:

*H1: FinTech adoption positively affects corporate investment efficiency.*

#### *ESG scores and corporate investment efficiency*

ESG performance plays an essential role in shaping corporate investment efficiency. Companies adopting strong ESG practices have better tools to communicate credibility to investors and regulators, minimize financing costs, and maximize capital allocation (Ellili, 2022; Tang et al., 2024; Bilyay-Erdogan et al., 2024). This mechanism may be particularly relevant in MENA markets, where disclosure requirements and regulatory enforcement vary considerably. In such contexts, ESG performance can reduce information asymmetry, enhance transparency, and mitigate both operational and reputational risks (Siddik et al., 2023; Al-Hiyari et al., 2023).

Several theoretical perspectives support this relationship. Stakeholder theory suggests that stronger ESG engagement enhances trust among investors, regulators, and society, facilitating access to capital and more efficient resource allocation (Freeman, 1984). From a Resource-Based View, ESG can be interpreted as a strategic intangible asset that improves legitimacy, governance quality, and long-term orientation, thereby supporting more informed and sustainable investment decisions (Lian and Weng, 2024). Agency theory further implies that ESG disclosure can reduce managerial opportunism by strengthening accountability and monitoring in ownership structures characterized by high concentration, as is common in many MENA countries (Rahman et al., 2025). Finally, institutional theory views ESG as a legitimacy signal that helps firms align with evolving regulatory norms in environments marked by fragmented enforcement or competing standards (Jiang et al., 2025; Liu, 2024). Empirical evidence shows that companies with high ESG scores are associated with better internal control, lower volatility, higher earnings forecast accuracy and stronger long-term financial performance (Lv and Xiong, 2022; Siddik et al., 2023). These results combined contribute to effective resource

allocation and exemplify the strategic value of ESG on investment efficiency. Moreover, ESG activities lead to trust of stakeholders, promoting investor confidence and lowering monitoring costs such that managers can take advantage of the best investment opportunities with low restrictions.

ESG adoption is of particular significance in MENA due to differences in institutional and regulatory contexts. Companies with high ESG scores are also more likely to capitalize on the digitalization trend, including by adopting new FinTech solutions, and meeting regulatory demands. Studies show that due to enhanced firm-level governance and information transparency, ESG adherence allows firms to exploit technological tools more efficiently and increase the possibility for investment efficiency gains (Lv and Xiong, 2022; Cao et al., 2024).

Therefore, the second hypothesis is presented as follows:

*H2: ESG scores positively affect corporate investment efficiency.*

#### *The influence of ESG scores as a moderator*

Additionally, ESG performance is theorized to moderate the relationship between FinTech adoption and corporate investment efficiency. While FinTech can enhance transparency, operational efficiency, and information dissemination, its effectiveness often depends on good governance quality, credibility and stakeholder trust. These conditions are more likely to be present in firms with stronger ESG performance, thereby enabling FinTech adoption to contribute more positively to investment efficiency. Conversely, in firms with weaker ESG scores, limited governance quality and lower credibility may reduce the benefits derived from digital financial technologies (Dhiyf et al., 2024; Cao et al., 2024).

Stakeholder theory helps explain this moderate role. Firms with ESG ratings tend to enjoy greater legitimacy and longer-term relationships with stakeholders, which increases confidence in digital disclosures by investors. Because FinTech relies heavily on trust and information quality, ESG performance can reduce the perceived noise of these signals and improve their effectiveness. Agency theory provides further support, suggesting that ESG reinforces governance structures, reduces managerial opportunism, and aligns managerial behaviors more closely with shareholder interests. This, in turn, enhances the capacity of FinTech platforms to mitigate the inefficiencies associated with costs of agency and improve investment returns (Siddik et al., 2023).

From an RBV, ESG and FinTech can be interpreted as synergistic - strategic assets. In addition, to the financial resources, ESG encompasses intangible value assets in terms of trust and goodwill from stakeholders as well as governance. These factors become amplifiers through which FinTech can generate greater organizational value. Firms that effectively integrate ESG practices with FinTech may therefore achieve better investment decisions, lower transaction costs, and more efficient allocation of capital (Qi et al., 2024; Wang et al., 2024).

Institutional theory also supports this interaction. In regions such as MENA, where regulatory enforcement and reporting standards remain uneven, ESG performance can serve as a signal of compliance and transparency that reduces institutional uncertainty and supports the disciplined use of FinTech. Firms with stronger ESG profiles are more likely to be perceived as reliable by regulators and investors, which enhances the legitimacy and effectiveness of FinTech-driven interventions (Liu, 2024; Dhiyf et al., 2024).

Institutional theory also supports this interaction. In regions such as MENA, where regulatory enforcement and reporting standards remain uneven, ESG acts as a source to reduce institutional uncertainty and support the disciplined use of FinTech. Companies with the best ESG scores are more likely to be perceived as reliable by regulators and investors, which enhances the legitimacy and effectiveness of FinTech-driven interventions (Liu, 2024; Dhiyf et al., 2024).

Empirical observations support this synergy. MENA firms that combine strong ESG performance with FinTech adoption exhibit greater investment efficiency, efficient resource allocation, lower monitoring costs, and reduced shareholder concerns (Du et al., 2023; Rahman

et al., 2025). By contrast, firms with weak ESG profiles often derive fewer benefits from their FinTech investment, as lower credibility and weaker governance structures limit their ability to fully exploit digital financial tools.

Thus, the study formulates a third hypothesis:

*H3: ESG scores, as a moderating factor, positively affect the relationship between FinTech adoption and corporate investment efficiency.*

Such a perspective helps to explain the conceptual disconnect between the direct and moderating effects of ESG by distinguishing its independent contribution to enhance FinTech effectiveness. In sum, the model proposed in Fig. 1 suggests a three-way relationship between FinTech adoption, ESG performance and the institutional context in shaping corporate investment efficiency in MENA countries.

### Methodological approach

#### Sample structure and demographic profile

The MENA ESG scores provide a useful basis for assessing the impact of FinTech transparency and ongoing regulatory reforms on investment efficiency of firms in the region (Table 1). To test this relationship, the empirical analysis relies on a panel data of 4417 firm-year observations for 547 different publicly listed companies in MENA region over the period from 2010 to 2024. Every observation is driven from a firm for the year. This panel is unbalanced, as not all firms are observed in every year, mainly because of the non-availability of ESG or financial data. To ensure data reliability and prevent spurious conclusions, firms with more than two consecutive years of missing data were excluded from the sample. Panel A of Table 1 describes the sample selection procedure, which begins with an initial pool of 12,748 firm-year observations.

The final sample reflects considerable sectoral and institutional diversity across the MENA region. Panel B of Table 1 reports the distribution of firms by industry and year, with the materials sector accounting for 19%, industrial use contains 14% and real estate containing 9% of the sample. Although the empirical analysis does not provide results by sector or year, these descriptive statistics indicate that the sample captures the main economic activities in the region. Such diversity is important for analyzing a heterogeneous context in which ESG adoption varies across industries and where the effectiveness of FinTech and investment outcomes may depend on differences in regulatory systems and institutional development across countries in the region.

The 15-year sample period provides enough time variation to account for short-run (immediate) and long-run (sustained) impacts of regulatory reforms, market uncertainty, and digital adoption on corporate investment behavior. This further captures firms' time-varying changes in ESG practices and FinTech adoption and how they evolve with sustainable governance and technological incorporation over time.

Sample design also finally meets the policy-relevant question of concern. Across the MENA region, mismatches in ESG reporting standards, the pace of digital development, and the strength of legal enforcement contribute to information inefficiencies and distortions in capital allocation. Targeting publicly traded firms with full two ESG and

financial information reports, the research points to companies that are more exposed to investor attentiveness and regulatory intervention and hence a clear setting in which the study can analyze how ESG & FinTech co-determine investment efficiency. For example, the study can observe from Table 2 considerable variability across countries: Kuwait and the UAE stand out as countries where firms perform well about ESG (78.62% and 70.27% of their firms are in the top quartile), while Oman and Turkey lag (48.97% and 38.58%, respectively). These divergences reflect the staggered uptake of ESG and FinTech among MENA countries, thereby identifying areas for policy intervention to improve corporate governance, transparency, and investment effectiveness.

#### Measures and definitions of key variables

To address this question, the study proposes a theory-based framework to help examine whether ESG performance would moderate the influence of FinTech adoption on corporate investment efficiency. Investment efficiency of firms is typically determined by using traditional models to calculate optimal investment volume as a function of company-specific financial and operational predictors. Departures from these predicted levels are proxies for over- or underinvestment and hence inefficiency in capital allocation.

In particular, the study uses the investment model of Richardson (2006) (Richardson4), which estimates firm fixed effects for investment based on lagged inverted U-shaped proxies. The study also includes lags of size, cash flow (cashflow), leverage (Lev), return on assets (ROA), and firm age when to estimate Richardson4. The residuals from this model are interpreted as measures of investment inefficiency: positive residuals indicate overinvestment, while negative residuals indicate underinvestment. Sector-specific controls are included in an expanded Richardson model (Richardson4\_m) for added precision, following Biddle et al. (2009) (Biddle4), that incorporates the growth opportunities by mean of market-to-book ratio, and Goodman et al. (2014) (Goodman3), which contains management's optimism in the form of forward-looking forecasts. Combined, these models are among the most parsimonious and widely used measures of investment efficiency measures in the literature (Richardson, 2006; Biddle et al., 2009).

FinTech adoption is measured using a region-specific proxy:  $FINT = \ln(1 + \text{number of FinTech firms in a country} - \text{year})$ .

This proxy measures the availability and penetration from which firm-level financial behaviors, such as investment efficiency might also stem. While this measure does not directly account for adoption at firm level, prior research shows that the regional density of FinTech development is associated with the extent to which firms are modernizing and integrating into digital financial ecosystems (Huang et al., 2024; Dhiab et al., 2024; Lv and Xiong, 2022; Qi et al., 2024). Natural logarithm is used to reduce the skewness in the distribution of FinTech across countries with differing levels of digital development.

ESG performance acts as a critical moderator, which denotes the integration of environmental, social and governance strategies. Data are obtained from Refinitiv's ESG database, which compiles more than 450 indicators across its Environmental (carbon emissions, resource use), Social (labor practices, human rights, customer responsibility) and Governance (board structure, audit practices and shareholder rights) dimensions. Company level ESG score (annual aggregate) is defined at the industry level. ESG theoretically moderates the FinTech-ICT relationship as firms with strong ESG profile tend to have better governance, credibility, and trust level (improved investor confidence) [Stakeholder Theory; Agency Theory; RBV; Institutional Theory]. Firms with poorer ESG scores might be unable to harness the full potential of FinTech innovations, as they are perceived less trustworthy or riskier.

To get an accurate estimation of this moderating effect, all continuous variables included in the interaction term are mean-centered. Mean-centering eliminates the collinearity between an interaction term and its constituent variables, thereby improving accuracy of estimation while preserving interpretability of a parameter's value.

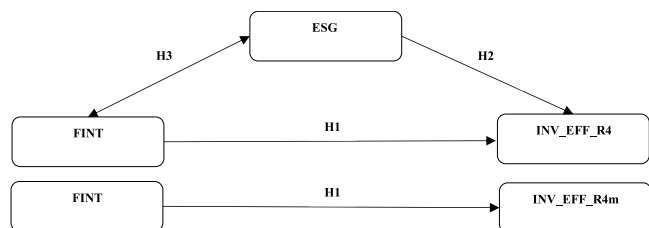


Fig. 1. Research Model.

**Table 1**  
Sample framework and descriptive analysis.

Panel A – Sample Selection					
<b>Details</b>					<b>Observations</b>
Initial firm-year observations (2010–2024) with ESG and investment efficiency data					12,748
Less: Observations excluded due to insufficient financial data					8331
Final sample of firm-year observations					<b>4417</b>
Panel B – By Industry and Year (ICB Classification)					
ICB Industry Classification	Observations	% of Sample	Year	Observations	% of Sample
Communication Services	222	5%	2010	104	2%
Consumer Discretionary	620	14%	2011	124	3%
Consumer Staples	355	8%	2012	128	3%
Energy	265	6%	2013	167	4%
Financials	355	8%	2014	162	4%
Health Care	355	8%	2015	201	5%
Industrials	620	14%	2016	282	6%
Information Technology	265	6%	2017	282	6%
Materials	841	19%	2018	342	8%
Real Estate	398	9%	2019	406	9%
Utilities	121	3%	2020	359	8%
			2021	445	10%
			2022	491	11%
			2023	458	10%
			2024	466	11%
<b>Total</b>	<b>4417</b>	<b>100%</b>	<b>Total</b>	<b>4417</b>	<b>100%</b>

Table 1 outlines the sampling framework, detailing the sample selection process (Panel A) and the distribution of 4417 firm-year observations across industries and years (Panel B).

**Table 2**  
Summary of ESG metrics across countries.

Country	Occurrence	% of Sample	Low ESG (%)	High ESG (%)
Bahrain	252	5.71%	37.3	62.7
Egypt	227	5.14%	45.81	54.19
Jordan	276	6.25%	33.7	66.3
Kuwait	318	7.20%	21.38	78.62
Lebanon	158	3.58%	45.57	54.43
Morocco	172	3.89%	46.51	53.49
Oman	388	8.78%	48.97	51.03
Qatar	435	9.85%	39.08	60.92
Saudi Arabia	731	16.55%	44.6	55.4
Tunisia	146	3.31%	41.78	58.22
Türkiye	648	14.67%	38.58	61.42
United Arab Emirates	666	15.08%	29.73	70.27
<b>Total</b>	<b>4417</b>	<b>100.00%</b>		

Note: Table 2 shows the distribution of firm-year observations and ESG score classifications across MENA countries from 2010 to 2024.

Formally, this interaction between ESG and FinTech shows the degree to which digital finance adoption effectiveness for investment efficiency depends systematically on firm-level ESG performance.

Control variables are added to account for firm-specific financial and operational characteristics that might confound the relationships of interest. These are firm size (SIZE, measured as the natural logarithm of total assets), leverage ratio (LEV, calculated by total debt divided by total assets), sales growth (GROW), return on assets (ROA) and revenue (REV), operating expenses (EXP), and capital expenditure (CAPEX). By including such controls, the estimated impacts of FinTech and ESG can be attributed to technology-specific sources and sustainability-related ones but not firm idiosyncratic differences (Benlemlih and Bitar, 2018; Ellili, 2022; Maiyami et al., 2024).

By incorporating these variables, the paper empirically investigates whether ESG performance has a moderating role in terms of the relationship between regional FinTech penetration and investment efficiency at firm level. This framework helps explain when the digital financial innovations contribute to capital allocation in MENA markets (see Du et al., 2023; Wang et al., 2024; Cao et al., 2024).

### Research design and conceptual structure

This paper constructs an internally consistent body of logic and empirical evidence that systematically incorporates the three central constructs—FinTech adoption, ESG performance, and corporate investment efficiency—into a theoretical informed analytical context. The model is developed on four complimentary theories: Stakeholder Theory, Agency Theory, the Resource Based View (RBV), and Institutional Theory. And each theory offers unique, yet complementary perspectives on the processes that underpin the relationship between these constructions. More specifically, Stakeholder and Agency Theories contend that firm good ESG practices contribute to reduce information asymmetry in the corporation activity, pointing out also the strengthening of transparency (Ellili, 2022; Benlemlih and Bitar, 2018), aspects which once combined with FinTech diffusion effectively cancel some investment inefficiencies. The RBV argues that FinTech and ESG resources operating together allow more efficient allocation of capital (Siddik et al., 2023; Gao et al., 2025). Institutional Theory also emphasizes the impact of regulative norms, and cross-country heterogeneity, which explains the inclusion of country and year fixed effects in the empirical models since both FinTech adoption and ESG practices are institutionally contingent (DiMaggio and Powell, 1983; Dhiaf et al., 2024).

Empirically, the study takes a multistage panel regression with data on 547 publicly listed MENA firms over the period 2010–2024. Corporate investment efficiency is defined as the difference between real and predicted investment using widely accepted benchmarks in finance literature (Richardson, 2006; Biddle et al., 2009; Goodman et al., 2014). Positive residuals signal overinvestment and negative residuals suggest underinvestment, both suggestive of misallocation of capital. For soundness, the study uses several models: Richardson4 and Richardson4\_m (which include sector controls), Biddle4 (which control for growth opportunities) and Goodman3 (which also includes management predictions).

The empirical analysis follows in three steps. Models 1 and 2 test for the direct influence of regional FinTech adoption against investment efficiency:

$$\text{InvestIneff}_{it} = \alpha + \beta_1 \text{FINT}_t + \beta_2 \text{Controls}_{it} + \text{Year}_{FE} + \text{Industry}_{FE} + \varepsilon_{it}$$

Models 3 and 4 examine the direct influence of firm-level ESG performance:

$$\text{InvestIneff}_{it} = \alpha + \beta_1 \text{ESG}_{it} + \beta_2 \text{Controls}_{it} + \text{Year}_{FE} + \text{Industry}_{FE} + \varepsilon_{it}$$

Finally, Models 5 and 6 test the moderating role of ESG in the relationship between FinTech and investment efficiency:

$$\text{InvestIneff}_{it} = \alpha + \beta_1 \text{FINT}_r + \beta_2 \text{ESG}_{it} + \beta_3 (\text{FINT} \times \text{ESG})_{it}$$

$$+ \beta_4 \text{Controls}_{it} + \text{Year}_{FE} + \text{Industry}_{FE} + \varepsilon_{it}$$

The interaction term ( $\beta_3$ ) captures whether the effect of FinTech adoption on investment efficiency is conditional on the level of ESG performance. A negative and significant coefficient implies that the impact of high ESG is to enhance the ability of FinTech in cutting investment inefficiency. To reduce multicollinearity and enhance interpretability, all continuous variables involved in an interaction are mean-centered. Extensive firm-level controls, such as size, leverage, sales growth, return on assets (ROA), revenue, operating expense, and capital expenditure are adopted to mitigate the omission variable bias and concentrate on the impact of FinTech and ESG. VIF diagnostics confirms the absence of significant multicollinearity ( $\text{all} \leq 5$ ).

For potential endogeneity in FinTech adoption influenced by reverse causality or unobserved firm-specific factors influencing both investment efficiency and FinTech adoption, the study adopts a Two-Stage - Least Squares approach (2SLS). The density of the regional FinTech entities is endogenous in the main model, and the study instrument is using lagged regulatory indicators as well as historical regional digital infrastructure development. First-stage F-statistics are above the standard cutoff of 15, and Hansen J-test results point to the relevance of instruments. All specifications are estimated using robust standard errors with clustering at the country level to allow for cross-country dependence, while year and industry fixed effects control for time varying macroeconomic shocks and sector specific trends.

Finally, Fig. 1 depicts a concept flow chart that describes the theoretical and published connections between the hypotheses (H1–H3). It focuses on the direct influence of FinTech and ESG on investment efficiency as well as the intermediary, moderating role of ESG in enhancing the impact of FinTech. This holistic approach contributes to a finer-grained understanding of how digital innovation and sustainability strategies mutually shape firm investment behavior in

the institutional environment of MENA.

### Empirical findings

#### Overview of descriptive measures and inter-variable correlations

Summary statistics and univariate comparisons provide an initial overview of ESG performance, use of FinTech, and investment efficiency at the firm level in the region (see Table 3). Panel A shows that firms have an average ESG score of 62.418, a moderate level of sustainability performance and mean FinTech adoption (FINT) is 3.218, revealing a moderate use of digital financial instruments in the region. Average investment efficiency (INV\_EFF\_R4) is  $-0.0020$ , meaning that firms do tend to over-invest or unallocated 1 row % under-invest relative to expected values. It is noteworthy that firms with fewer FinTech adopters are likely to have lower investment efficiency, thus confirming theoretical predictions from stakeholders and resource-based theories that digital financial inclusion leads to a more efficient allocation of capital.

Panel B shows significant differences between high- and low-ESG firms. High-ESG companies have reported a FINT score 25.7% higher than that of their low-ESG counterparts (3.612 vs.2.874, p-value =0.021) and investment efficiency more than twice as high (0.003 vs 0.001, p-value= 0.023). These firms are also bigger (SIZE: 9.828 versus 8.659, p = 0.019), more leveraged (LEV: 0.391 versus 0.346, p = 0.026) and more profitable (ROA: 0.094 versus, p = 0., indicating that good ESG performers do not only operate at a larger scale but also feature better financial health.0417 vs.), as that only is due to the larger size of those companies because a regression reveals that small firms do not perform worse regarding excess returns in case of triple A-rated GMI ratings. These results provide tentative evidence that ESG performance might strengthen the positive effect of FinTech on investment efficiency by enhancing firm credibility, governance quality, and access to financial resources.

Additional insight into the relationships among these variables is provided by Table 4, which displays pairwise correlations. ESG is positively associated with FINT (0.44) and investment efficiency (INV\_EFF\_R4: 0.36; INV\_EFF\_R4m: 0.34), indicating that firms with

**Table 3**  
Group-level descriptive statistics and central tendency analysis.

Panel A – Descriptive Statistics								
Variable	Observations	Mean	Std. Dev.	Min	P25	Median	P75	Max
INV_EFF_R4	4417	0.0020	0.1685	0.0000	0.0000	0.0000	0.0002	7.4521
INV_EFF_R4m	4417	0.0026	0.2953	0.0000	0.0000	0.0000	0.0003	5.2987
FINT	4417	3.2175	2.0812	0.0000	1.3105	2.9862	5.2814	8.1983
ESG	4417	62.418	22.764	13.770	45.030	62.080	79.670	97.540
CSR	4417	48.893	19.761	10.940	32.720	47.920	65.310	93.860
SIZE	4417	9.241	1.497	6.840	7.850	9.220	10.380	13.090
LEV	4417	0.3689	0.2948	0.0295	0.2887	0.5710	0.7394	0.9854
GROW	4417	0.0892	0.7974	-4.2034	-0.0220	0.1589	0.6538	0.8991
ROA	4417	0.0874	0.0660	-0.0480	0.0340	0.0840	0.1210	0.2390
REV	4417	510.84	208.31	129.57	392.74	497.41	586.12	889.67
EXP	4417	318.73	167.45	89.64	260.35	308.52	371.41	616.78
CAPEX	4417	0.2003	0.1934	0.0011	0.1527	0.1598	0.7816	0.8143
Panel B – Sub-Samples Separated Based on the Industry Median of ESG								
Variable	Low ESG Mean	Low ESG Median	High ESG Mean	High ESG Median	Mean Test (p-value)		MW Test (p-value)	
INV_EFF_R4	0.001	0.000	0.003	0.000	0.023		0.030	
INV_EFF_R4m	0.002	0.000	0.003	0.000	0.018		0.025	
FINT	2.874	2.540	3.612	3.282	0.021		0.028	
SIZE	8.659	8.512	9.828	9.795	0.019		0.027	
LEV	0.346	0.310	0.391	0.362	0.026		0.034	
GROW	0.074	0.058	0.103	0.093	0.022		0.030	
ROA	0.069	0.063	0.094	0.089	0.017		0.024	
REV	472.2	458.3	535.0	520.8	0.029		0.036	
EXP	297.8	287.2	339.7	331.5	0.027		0.033	
CAPEX	0.179	0.158	0.221	0.198	0.024		0.031	

Note: Table 3 presents the descriptive statistics and univariate comparisons of key variables across low and high ESG score groups, using both t-tests and Mann–Whitney U tests. Definitions for all variables can be found in Table A. The authors jointly conducted the analysis.

**Table 4**  
Correlation matrix of key variables.

Variable	INV_EFF_R4	INV_EFF_R4m	FINT	ESG	SIZE	LEV	GROW	ROA	REV	EXP	CAPEX	VIF
INV_EFF_R4	1											
INV_EFF_R4m	0.89	1										
FINT	0.41	0.38	1									2.64
ESG	0.36	0.34	0.44	1								2.76
SIZE	0.29	0.27	0.46	0.32	1							3.04
LEV	0.21	0.22	0.33	0.3	0.35	1						2.12
GROW	0.23	0.21	0.27	0.28	0.38	0.18	1					2.19
ROA	0.25	0.26	0.31	0.34	0.3	0.19	0.36	1				2.08
REV	0.22	0.2	0.35	0.26	0.75	0.29	0.31	0.28	1			3.12
EXP	0.18	0.17	0.29	0.24	0.62	0.33	0.29	0.24	0.68	1		2.84
CAPEX	0.31	0.29	0.3	0.23	0.49	0.28	0.35	0.26	0.59	0.52	1	2.59

Note: Table 4 presents the Pearson correlation coefficients among the key study variables. Variance Inflation Factor (VIF) values confirm that multicollinearity is within acceptable limits. Definitions of all variables are listed in Table A.

higher ESG scores are more likely to avail themselves of digital financial technologies, which enhance the efficient distribution of capital. FinTech adoption is also positively related to SIZE (0.46), revenue (REV: 0.35), leverage (LEV: 0.33) and profitability (ROA: 0.31) which indicate that larger, better capitalized, and more profitable firms can execute digitized tools optimizing the investment results.

Table 3 also reports skewness and kurtosis to give a full description, which shows that the probability density function of all variables is normal. Outliers were treated using winsorization at the 1st and 99th percentiles to limit extreme values without influencing central trends. Furthermore, multicollinearity is not a significant factor (all VIFs < 5) and both ESG and FINT were mean centered before computing interaction terms were generated to retain interpretability of the regression coefficients and maintain unbiased estimation with respect to the moderation effects.

*Econometric analysis of relationships*

The results from both the direct and moderating effects of FinTech adoption (FINT) and ESG performance on investment efficiency of the MENA companies are shown in Table 5. Motivated from the theoretical discussion as described above, stakeholder theory, agency theory, RBV and institutional theory all predict that both FinTech adoption and ESG performance have positive effects on investment efficiency while ESG is an enhancer of the effect of FinTech.

Beginning with the direct impact of Fintech, it is established by Models 1 and 2 that FINT has a positive and meaningful relationship with investment efficiency (INV\_EFF\_R4: 0.115, t = 4.32; INV\_EFF\_R4m: 0.108, t = 4.08). Groh, Kohl, and Dibiasi show that a 1-unit change in

FINT—equivalent to an approximate doubling of their number of local FinTech companies—is linked with an 11–10% increase in investment efficiency. These results are in coherence with previous studies that digital financial infrastructure lowers transaction costs, enhances financial transparency and facilitates more informed managerial decision-making (Lin et al., 2023; Dhiab et al., 2024).

Models 3 and 4 then test the direct impact of ESG performance. ESG is positively associated with both measures of investment efficiency (INV\_EFF\_R4: 0.102, t = 3.98; INV\_EFF\_R4m: 0.095, t = 3.72), indicating that a ten-point improvement in ESG scores on a scale from 0 to 100 results in an approximately one percent increase in investment efficiency. This is consistent with the stakeholder and agency theories: stronger ESG practices enhance internal mechanisms, decrease asymmetric information, increase investor confidence, and thus improve resource allocation.

More importantly, the interaction term (FINT × ESG) remains positive and statistically significant in Models 5 and 6 (INV\_EFF\_R4: 0.063, t = 2.45; INV\_EFF\_R4m: 0.058, t = 2.31), which offers empirical evidence for the hypothesized moderating effect of ESG. Marginal effect analysis also suggests that the influence of FinTech adoption on investment efficiency is strengthened for firms with better ESG performance; firms at the 75th percentile of ESG scores realize two times more efficiency gains from FinTech adoption than their 25th-ESG peers. Such evidence justifies the theoretical presumption that ESG enhances credibility, good governance and confidence of key stakeholders that are necessary conditions for the effects of FinTech innovations to fully manifest.

The introduction of the interaction term also enhances model fitness. R<sup>2</sup> increases to 0.235 for INV\_EFF\_R4 and 0.225 for

**Table 5**  
Regression findings using OLS method.

Variable	Model 1 (INV_EFF_R4)	Model 2 (INV_EFF_R4m)	Model 3 (INV_EFF_R4)	Model 4 (INV_EFF_R4m)	Model 5 (INV_EFF_R4)	Model 6 (INV_EFF_R4m)
FINT	0.115***	0.108***	–	–	0.098**	0.090**
ESG	–	–	0.102***	0.095***	0.085**	0.080**
FINT × ESG	–	–	–	–	0.063**	0.058**
SIZE	0.036	0.033	0.035	0.031	0.032	0.029
LEV	0.124***	0.120***	0.121***	0.118***	0.117***	0.114***
GROW	0.051*	0.048*	0.049*	0.045*	0.044*	0.041*
ROA	0.018	0.017	0.017	0.015	0.016	0.014
REV	0.039	0.036	0.038	0.034	0.034	0.03
EXP	-0.028	-0.026	-0.027	-0.024	-0.023	-0.021
CAPEX	0.055**	0.051**	0.053**	0.050**	0.047**	0.044**
Intercept	0.110***	0.105***	0.108***	0.102***	0.103***	0.098***
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.19	0.18	0.185	0.175	0.235	0.225
Adj. R-squared	0.15	0.14	0.145	0.135	0.195	0.185
Observations	4417	4417	4417	4417	4417	4417

Note: Table 5 presents the OLS regression results for six models, detailing significance levels, goodness-of-fit measures, and the application of year and industry fixed effects. Variable definitions can be found in Table A. The results represent a collaborative effort by the author.

INV\_EFF\_R4m, respectively also adjusted R<sup>2</sup>, this synergetic effect regarding high ESG practices when combined with the adoption of FinTech has a statistically significant impact on our criteria over and above the joint main effects. These findings underscore the significance of aligning sustainable and digital finance strategies to maximize corporate investment, especially in institutionally complex and resource-rich transitioning regions such as MENA.

In sum, the findings are in line with the expected channels of the conceptual model: FinTech fosters investment efficiency, ESG does so directly and their interaction yields more benefits. This subsequently proves that the impact digital financial innovations on resource allocation depends on corporate ESG performance, which is consistent with extant empirical evidence (Lin et al., 2023; Dhiyf et al., 2024).

Lastly, all specifications pass common diagnostic checks to determine multicollinearity (VIF < 5), and instrumental variable testing for endogeneity suggests validity of instruments with first-stage F-statistics above 15 and Hansen J-tests supporting exogeneity. These tests yield further confidence in the validity of the econometric specifications and provide additional support for interpreting the results as theoretically based.

*Robustness checking and extended results*

This paper performs a battery of robustness tests to verify the reliability as well as facilitate robustness of method and to guard against ‘statistical artefacts’ in the observed linkages between FinTech adoption, ESG performance and corporate investment efficiency. The key -tasks are to control sample selection bias, endogeneity, and measurement issues, as well as to check the robustness of the interaction effect throughout different specifications.

To guarantee the reliability and validity of the main findings, this paper performs a series of robustness tests. These tests attempt to account for sample selection bias, endogeneity and measurement

problems as well as to test the robustness of the interaction effect across different model formulations. Hence, the study can be assured that the associations between FINT adoption and ESG performance and corporate investment efficiency are not spurious but indicative of appropriate economic phenomena.

Table 6 The results using the Heckman selection model Table 6 reports estimates based on a Heckman two stage selection model (Heckman, 1979), which mitigates potential endogenous sample selection bias. The first stage estimates the probability of a firm having high ESG scores in Probit regressions, and the second stage corrects for selection effects using inverse Mills ratio (IMR). The findings in Table 5 show that both FinTech adoption and ESG performance are positively associated with investment efficiency, and more importantly, interaction term (FINT × ESG) is still positive significant (Model 6: β = 0.060). This evidence points to the combination of FinTech and ESG not being due to selection bias. In addition, year and industry fixed effects are added for robustness and to control for macroeconomic and sectoral differences.

Second, results from Two-Stage Least Squares (2SLS) regressions. Table 7 is presented to allay the reverse causality or omitted variable bias concerns via controlling for potential endogeneity issues (Bollen, 1996). The study instrument ESG ratings here, the better Hugo Boss is doing with firm ESG scores for exogenous variation in FinTech penetration. The findings verify that FINT and ESG are still positively correlated with investment efficiency where the interaction term is significant (Model 6: 0.058). The first stage F-statistics is well above the rule of thumb value of 15, and Hansen J-test confirms the relevance of the instruments which together reassure that it is not endogeneity that is driving our results.

Third, Table 8 examines alternative measures to confirm the results. Panel A substitutes Biddle4 and Goodman4 with various common investment efficiency proxies, while Panel B replaces ESG scores with corporate social responsibility (CSR) scores introduced by Yu and Xiao

**Table 6**  
Robustness check: Heckman two-stage selection model (1979 Approach).

Panel A – Initial Stage: High ESG (PSM) Analysis							
Variable	High ESG	Model 1 (INV_EFF_R4)	Model 2 (INV_EFF_R4m)	Model 3 (INV_EFF_R4)	Model 4 (INV_EFF_R4m)	Model 5 (INV_EFF_R4)	Model 6 (INV_EFF_R4m)
FINT	0.110***	0.085***	0.075***	-	-	0.045**	0.040**
ESG	-	-	-	0.095***	0.105***	0.035*	0.042*
FINT × ESG	-	-	-	-	-	0.055**	0.060**
SIZE	0.01	0.012	0.008	0.007	0.005	0.006	0.004
LEV	0.060**	0.045**	0.040**	0.035*	0.030*	0.025*	0.020*
GROW	0.015	0.02	0.018	0.017	0.014	0.012	0.01
ROA	0.005	0.008	0.006	0.004	0.003	0.002	0.001
REV	0.002	0.003	0.002	0.002	0.002	0.001	0.001
EXP	-0.008	-0.005	-0.004	-0.006	-0.005	-0.004	-0.003
CAPEX	0.020**	0.022**	0.018**	0.015*	0.014*	0.013*	0.011*
Intercept	1.180***	1.150***	1.130***	1.140***	1.120***	1.110***	1.100***
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Model Fit (R <sup>2</sup> / Pseudo R <sup>2</sup> )	0.49	0.37	0.35	0.36	0.34	0.32	0.31
Observations	4417	4417	4417	4417	4417	4417	4417
Panel B – Comparison of Means Between Treatment and Control Groups							
Variable	Treated Group			Control Group			p-value
SIZE	4.01			3.985			0.185
LEV	0.48			0.46			0.215
GROW	0.042			0.039			0.16
ROA	0.037			0.033			0.098
REV	5210			5100			0.275
EXP	1230			1210			0.345
CAPEX	420			400			0.29

Note: Table 6 reports results from a two-stage Heckman selection model. The first stage estimates the probability of high ESG scores via probit regression, while the second stage corrects for selection bias with the Inverse Mills Ratio. Models 1–2 examine FinTech adoption effects, Models 3–4 assess ESG impacts, and Models 5–6 explore ESG’s moderating role. Robust standard errors and fixed effects are applied. Significance levels are marked with \*\*\*, \*\*, and \*. Variable definitions are in Table A, based on 4417 observations.

**Table 7**

Robustness check: two-stage least squares (2SLS) regression results.

Variable	High ESG	Model 1 (INV_EFF_R4)	Model 2 (INV_EFF_R4m)	Model 3 (INV_EFF_R4)	Model 4 (INV_EFF_R4m)	Model 5 (INV_EFF_R4)	Model 6 (INV_EFF_R4m)
FINT	0.082***	0.060**	0.058**	-	-	0.045*	0.047*
ESG	-	-	-	0.072**	0.069**	0.063**	0.067**
FINT × ESG	-	-	-	-	-	0.055**	0.058**
SIZE	-0.015	0.02	0.018	0.022	0.02	0.021	0.019
LEV	0.045**	0.03	0.028	0.032	0.029	0.027	0.025
GROW	0.01	0.008	0.007	0.006	0.007	0.005	0.006
ROA	0.004	0.002	0.003	0.001	0.002	0.002	0.001
REV	0.012	0.011	0.01	0.009	0.01	0.008	0.009
EXP	-0.005	-0.004	-0.003	-0.003	-0.004	-0.002	-0.003
CAPEX	0.008	0.007	0.006	0.007	0.006	0.005	0.006
Intercept	1.120***	1.050***	1.040***	1.060***	1.055***	1.045***	1.050***
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Model Fit Statistics							
R <sup>2</sup> / Pseudo R <sup>2</sup>	0.52	0.25	0.27	0.29	0.28	0.3	0.26
Observations	4417	4417	4417	4417	4417	4417	4417
Hansen J Stat	0.11	0.1	0.09	0.08	0.07	0.06	0.05
Endogeneity Test	0.32	0.3	0.31	0.29	0.28	0.27	0.26

Note: This table shows Two-Stage Least Squares (2SLS) regression results examining the effects of FinTech adoption, ESG scores, and their interaction on investment efficiency (Richardson4 and Richardson4\_m). High ESG firms are used as an instrument. Models control firm characteristics and include year and industry fixed effects. Significance levels are indicated by \*\*\*, \*\*, and \*. Variable definitions are in Table A. The sample includes 4417 observations.

**Table 8**

Robustness check: alternative variable measurements.

Panel A: Alternative Investment Efficiency Measures						
Variable	Model 1 (Biddle4)	Model 2 (Goodman4)	Model 3 (Biddle4)	Model 4 (Goodman4)	Model 5 (Biddle4)	Model 6 (Goodman4)
FINT	0.067**	0.065**	-	-	0.055*	0.057*
ESG	-	-	0.070**	0.068**	0.062**	0.064**
FINT × ESG	-	-	-	-	0.060**	0.063**
SIZE	0.021	0.02	0.023	0.021	0.022	0.02
LEV	0.052**	0.051**	0.054**	0.053**	0.055**	0.053**
GROW	0.011	0.01	0.012	0.011	0.01	0.011
ROA	0.013	0.012	0.013	0.013	0.012	0.012
REV	0.014	0.013	0.015	0.014	0.014	0.013
EXP	-0.006	-0.005	-0.005	-0.006	-0.005	-0.006
CAPEX	0.007	0.006	0.007	0.007	0.006	0.006
Intercept	0.135**	0.130**	0.138**	0.134**	0.137**	0.133**
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.11	0.11	0.12	0.12	0.13	0.13
Adj. R-squared	0.09	0.09	0.1	0.1	0.11	0.11
Observations	4417	4417	4417	4417	4417	4417
Panel B: Alternative ESG Measurement						
Variable	Model 1 (INV_EFF_R4)	Model 2 (INV_EFF_R4m)	Model 3 (INV_EFF_R4)	Model 4 (INV_EFF_R4m)	Model 5 (INV_EFF_R4)	Model 6 (INV_EFF_R4m)
FINT	0.062**	0.060**	-	-	0.052*	0.054*
CSR	-	-	0.065**	0.063**	0.060**	0.061**
FINT × CSR	-	-	-	-	0.057**	0.058**
SIZE	0.02	0.019	0.021	0.02	0.021	0.019
LEV	0.053**	0.052**	0.054**	0.052**	0.054**	0.052**
GROW	0.012	0.011	0.013	0.012	0.012	0.012
ROA	0.004	0.004	0.005	0.004	0.004	0.004
REV	-0.006	-0.006	-0.006	-0.005	-0.006	-0.006
EXP	-0.014	-0.014	-0.015	-0.014	-0.015	-0.014
CAPEX	0.009	0.009	0.01	0.009	0.01	0.009
Intercept	0.128**	0.125**	0.130**	0.127**	0.130**	0.128**
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.1	0.1	0.11	0.11	0.12	0.12
Adj. R-squared	0.08	0.08	0.09	0.09	0.1	0.1
Observations	4417	4417	4417	4417	4417	4417

Note: This table reports robustness checks using alternative measures of investment efficiency and ESG performance to confirm the main findings. Panel A applies Biddle4 and Goodman4 as alternative proxies for investment efficiency, while Panel B uses a CSR score in place of ESG. Across both panels, the models test the individual and interactive effects of FinTech adoption (FINT) and ESG/CSR scores. All regressions are estimated using OLS with robust standard errors clustered at the firm level and include year and industry fixed effects. Superscripts \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Definitions for all variables are provided in Table A. The total number of observations is 4417. The analysis reflects collaborative contributions from the author.

(2022) to examine the cross-market generality. The impact of FinTech and ESG/CSR on investment efficiency is robust,  $FINT \times CSR$  is significantly negative (Model 6:  $-0.058$ ), suggesting that the synergy between digital finance and sustainability is universal with related constructs. \*\*

Fourth, the robustness of the estimates with respect to time and simultaneity is analyzed in Table 9. Panel A controls the period of the COVID-19 pandemic and indicates that the main relations are weakened but remain robust, meaning no structural break due to exogenous shocks. Panel B controls for lagged independent variables ( $t - 1$ ) due to endogeneity problems (Horwitz et al., 2021). With lagged terms, the interaction term ( $FINT \times ESG$ ) is still significant at 10% (Model 12: 0.024), indicating the stability of synergy effects between FinTech and ESG across time.

Finally, Table 10 gives OLS baseline results for reference. Models 1 – 4 demonstrate that both variables, FINT and ESG, have positive and significant effects on investment efficiency, and Models 5 – 6 reveal the interaction term is significantly positive (0.063, 0.058). All VIFs are lower than 5 and interaction terms are mean centered to address multicollinearity. Comparisons to models without inclusion of control variables emphasize the necessity of including firm-level characteristics as the omission leads to reduced explanatory power and coefficient sizes.

### Discussion and conclusion

This paper investigates the nexus between ESG performance and FinTech adoption on corporate investment efficiency in the MENA region, providing insights into how sustainability activities and digital finance together affect firm-level allocation of capital. Taken together, they reflect that FinTech and ESG are both positively associated with investment efficiency, and more importantly, that the adoption of FinTech is significantly increased by ESG. These results indicate the importance of strategic complementarity between sustainability and digital finance in institutional settings characterized by fragmented

markets and heterogeneous regulatory policies (as in MENA countries).

Conceptually, this study draws on Resource-Based View (RBV), Stakeholder Theory, Agency Theory, and Institutional Theory that provide mutually supportive theoretical perspective. RBV conceptualizes ESG performance as a strategically valuable intangible asset which enhances firm capabilities, lessens information asymmetry and competitive strength (Benlemlih and Bitar, 2018; Gao et al. 2025). From this perspective, high-ESG companies maintain stronger internal controls and risk monitoring devices, their governance is more transparent that initiates trust to investors, regulators, and other stakeholders (Harymawan et al., 2022; Freeman, 1984). Additionally, ESG systems allow for consistent reporting and forecastable risk profiles, which helps in obtaining capital and reducing uncertainty (Al-Hiyari et al., 2023; Maiyarni et al., 2024). As a result, better ESG-compliant firms are for sure those that are in a condition of benefiting more from their FinTech tools, thus confirming the existence of a complementarity between sustainability and technological adoption.

Regarding H1, the study finds evidence to suggest that the regional FinTech adoption (FINT) is positively associated with investment efficiency, especially among firms with higher ESG performance (Huang 2022). This relationship is economically intuitive, as digital financial technologies can improve capital allocation through several channels. Tools such as real-time financial analytics, blockchain-based reporting, automated compliance systems, and digital credit scoring can reduce transaction costs, enhance transparency, and support more timely and informed investment decisions. These mechanisms may be particularly relevant in the MENA region which is dominated by MENA markets whereby small and medium enterprises (SMEs) and where non-traditional investors frequently face obstacles to access to capital (Qi et al., 2024; Siddik et al., 2023). In such contexts, the expansion of the FinTech ecosystem can help alleviate structural financing frictions and improve the matching between investment opportunities and available funds. Economically, a unit increase in FINT (the number of

**Table 9**

Robustness check: supplementary and extended analyses.

Panel A. Addressing COVID-19 (Years removed or adjusted)						
Variable	Model 1 (INV_EFF_R4)	Model 2 (INV_EFF_R4m)	Model 3 (INV_EFF_R4)	Model 4 (INV_EFF_R4m)	Model 5 (INV_EFF_R4)	Model 6 (INV_EFF_R4m)
FINT	0.062**	0.059**				
ESG	-2.11	-2.05	0.073**	0.069**		
FINT × ESG			-2.3	-2.21	0.027*	0.023*
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
R <sup>2</sup>	0.24	0.23	0.26	0.25	0.28	0.27
Observations	3930	3930	3930	3930	3930	3930
Panel B. Addressing Simultaneous Causality (Lagged Independent Variables at t-1)						
Variable	Model 7 (INV_EFF_R4)	Model 8 (INV_EFF_R4m)	Model 9 (INV_EFF_R4)	Model 10 (INV_EFF_R4m)	Model 11 (INV_EFF_R4)	Model 12 (INV_EFF_R4m)
FINT <sub>t-1</sub>	0.060**	0.057**				
ESG <sub>t-1</sub>	-2.05	-1.98	0.070**	0.066**		
FINT × ESG <sub>t-1</sub>			-2.25	-2.15	0.026*	0.024*
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
R <sup>2</sup>	0.23	0.22	0.25	0.24	0.27	0.26
Observations	3780	3780	3780	3780	3780	3780

Note: This table presents Panel A reports baseline models, while Panel B addresses simultaneity by incorporating lagged independent variables ( $t-1$ ). All models include firm-level controls, year, and industry fixed effects, with robust standard errors clustered at the firm level. t-statistics are shown in parentheses, and statistical significance is denoted by \*, \*\*, and \*\*\* for the 10%, 5%, and 1% levels, respectively. Slight variation in observations in Panel B is due to lagged data.

**Table 10**  
Benchmark results: baseline regression model.

Variable	Model 1 (INV_EFF_R4)	Model 2 (INV_EFF_R4m)	Model 3 (INV_EFF_R4)	Model 4 (INV_EFF_R4m)	Model 5 (INV_EFF_R4)	Model 6 (INV_EFF_R4m)
<b>Panel A: Controls (Yes)</b>						
FINT	0.115***	0.108***	–	–	0.098**	0.090**
ESG	–	–	0.102***	0.095***	0.085**	0.080**
FINT × ESG	–	–	–	–	0.063**	0.058**
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.19	0.18	0.185	0.175	0.235	0.225
Adj. R-squared	0.15	0.14	0.145	0.135	0.195	0.185
Observations	4417	4417	4417	4417	4417	4417
<b>Panel B: Controls (No)</b>						
FINT	0.041	0.038	–	–	0.035	0.03
ESG	–	–	0.04	0.036	0.031	0.028
FINT × ESG	–	–	–	–	0.024	0.02
Controls	No	No	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.045	0.04	0.048	0.042	0.053	0.047
Adj. R-squared	0.038	0.033	0.041	0.035	0.046	0.04
Observations	4417	4417	4417	4417	4417	4417

Note: The results in Table 10 show that the inclusion of control variables significantly strengthens. In Panel A Controls (Yes), the coefficients are larger and statistically significant, indicating robust relationships. In contrast, Panel B: Controls (No) shows notably weaker and insignificant coefficients, along with lower R-squared values, suggesting that omitting key firm-level controls diminishes explanatory power and may lead to biased inferences, denoted by \*, \*\*, and \*\*\* for the 10%, 5%, and 1% levels, respectively. Definitions for all variables are provided in Table A. The total number of observations is 4417. The analysis reflects collaborative contributions from the author.

new regional FinTech firms' doubles) is found to be associated with around 11.5% improvement in investment efficiency, supporting the actual benefits from using digital finance for resource allocation.

With respect to the H2, the results support the fact that companies with higher ESG scores have better investment efficiency (Ellili, 2022; Gao et al., 2025). 10 points increase in ESG score leads to around 1% increase in investment allocation, which demonstrates the concrete advantages related to strong sustainability performances. RBV claims ESG as an intangible strategic asset, enriches firm performance and robustness (Barney, 1991), while Stakeholder Theory argues that firms with high ESG scores will foster trust and cooperation from investors, regulators and other important stakeholders which helps companies financing in the long run and capital allocation efficiency (Freeman, 1984; Al-Hiyari et al., 2023). Empirical evidence supports this view, with studies demonstrating the positive effect of ESG on transparency in operations, risk management, resource allocation, and output (Maiyarni et al., 2024; Rahman et al., 2025).

Lack of in-depth understanding in summary, H3 is well supported that ESG significantly moderates the impact of Fintech adoption on investment efficiency. The sign of the interaction term (FINT × ESG) is positive and significant on both Model 3 (0.063) and Model 4 (0.058), suggesting that FinTech benefits are being magnified in companies with higher levels of ESG performance (Dhiaf et al., 2024; Wang et al., 2024). For instance, firms with 75th percentile of ESG score achieve more than twice the efficiency improvement benefits when they adopt FinTech compared to firms at 25th percentile showing that value-addition to industry by ESG governance and digital financial integration are complementary. This neutralizing impact can be rationalized by the oversight and accountability of ESG data, which offers trust-worthy and transparent signals that enhance the effectiveness of FinTech analytics for investment decision-making (Lin et al., 2023; Maiyarni et al., 2025).

From an Agency Theory viewpoint, ESG decreases information asymmetry that exists between managers and shareholders which is not negligible in MENA markets with concentrated shareholding structure and weak governance (Benlemlih and Bitar, 2018). Through enabling structured reporting and transparent disclosure, ESG helps mitigating conflicts of interest and boosting manager confidence in making the appropriate investment decisions supported by the real-time financial

performance tracking provided via FinTech (Ellili, 2022; Qi et al., 2024). Moreover, Institutional Theory predicts that ESG uptake is the result of both formal mandates and less well-defined social norms, which are highly divergent among MENA countries (DiMaggio and Powell, 1983; Rahman et al. 2025). FinTech in less strict jurisdictions can complement this by providing a standardized reporting framework, consequently increasing the strategic importance of ESG in the investment efficiency.

These results reflect the distinctiveness of MENA markets. Compared with developed economies, where ESG frameworks and digital financial ecosystems are already well established, firms in the MENA region may experience larger efficiency gains even at moderate levels of FinTech and ESG adoption. This suggests that, in emerging economies, ESG does not function solely as a signal of sustainability performance, but also as a mechanism that strengthens the legitimacy and effectiveness of digital financial innovations by helping firms compensate for institutional and regulatory gaps (Siddik et al., 2023; Cao et al., 2024). Although past studies have warned that weak ESG regulation may curtail the expected benefits (Lian and Weng, 2024), the current findings illustrate how credible ESG reporting coupled with FinTech adoption can still lead to substantial improvements in capital allocation, even in environments characterized by uneven enforcement and fragmented governance structures.

The robustness of these findings is also verified by several checks. Both Heckman two-stage regressions and Two-Stage Least Squares (2SLS) address threats to validity: sample selection bias (Heckman, 1979) and endogeneity bias (Bollen, 1996), respectively. Hansen J-statistics support the validity of instruments and alternative proxies for investment efficiency (Biddle et al., 2009; Goodman et al., 2014) as well as the corporate social responsibility (CSR) scores (Yu and Xiao, 2022) yield consistent results that confirm our results. All continuous variables were mean centered in the interaction terms, and VIFs were less than 5 indicating no serious multicollinearity problems (Benlemlih and Bitar, 2018; Maiyarni et al., 2024).

From a policy standpoint, the implications of these findings are significant. Regulators ought to be encouraged to develop ESG disclosure regimes that reflect and respect institutional diversity in MENA, which should improve transparency, lower risk of investment and more

efficiently allocate capital (Tang et al., 2023; Qi et al., 2024). Public-private partnerships and regulatory sandboxes can facilitate the responsible implementation of FinTech, especially when it is associated with sustainability goals. Also, ESG related regulatory initiatives improve the quality of data in FinTech systems increasing investor trust and encouraging responsible investing. Such interventions are especially important in emerging markets characterized by weak ESG reporting and fragmented digital infrastructure, which would otherwise impede deployment of capital (Rahman et al., 2025).

From a managerial perspective, ESG factors should be incorporated into digital finance strategies. Firms ought to incorporate sustainability into designing Fintechs tools for investment decision-making processes, regulation compliance, and stakeholder commitment Firms with stronger ESG profiles that adopt digital finance tend to benefit from lower transaction costs, better access to financing options, and greater confidence from investors which lead to more efficient and sustainable capital allocation (Lin et al., 2023; Siddik et al., 2023).

Despite its contributions, this study has several limitations that should be noted. First, the use of publicly reported ESG scores may understate or ignore how deeply and well ESG considerations are embedded in firms; these scores capture what is on paper rather than what is happening operationally. To conduct research on how ESG gets ‘turned into practice, future research may want to add qualitative case studies or management interviews to the quantitative analysis. Second, the analysis assumes a linear association between ESG and investment efficiency, but non-linear effects (e.g., saturation), or threshold effects at which efficiency gains will not increase further for extremely elevated levels of ESG would be interesting topics for future research. Third, the present study is conducted using publicly traded firms in the MENA, and does not consider private-held companies, or small and micro-sized enterprises that might act differently toward ESG adoption and FinTech usage. Fourth, it would be interesting to do cross-regional comparisons and examine whether these mechanisms apply in non-US markets with a more developed ESG reporting system and digital finance infrastructure. Lastly, even though this study mitigates endogeneity problems by using 2SLS and Heckman model, there could still be unobserved country-level institutional variables or firm-specific -behavioral characteristics affecting the relationships observed. It is therefore recommended to mitigate these limitations to improve the external validity of the findings and provide insights into ESG-FinTech relations.

To sum up, our evidence suggests that ESG performance plays an essential moderating role in the relationship between FinTech adoption and corporate investment efficiency in MENA. Through transparency, agency conflict mitigation and credibility of capital, ESG keeps the digital financial tools running well. These results provide practical recommendations to practitioners, policymakers, and investors for the development of sustainable technology-based corporate investment

planning in emerging markets. MENA businesses can help optimize the flow of capital, build trust with stakeholders and contribute to sustainable national development by incorporating ESG principles into digital finance plans.

Overall, evidence supports theoretical consolidation of RBV, Stakeholder theory and Agency theories with practical contributions to SDGs. By integrating sustainability and digital finance adoption, companies will be able to enhance market efficiency, solve institutional problems, promote sustainable economic development, and thus strengthen the strategic significance of ESG-FinTech integration in emerging markets.

### Ethical Approval

This study does not involve human participants or personal data requiring ethical approval. All data used are secondary and obtained from publicly available or licensed databases.

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### CRedit authorship contribution statement

**AlQudah Mohammad Zakaria:** Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Zyad Marshdeh:** Writing – original draft, Project administration, Methodology, Investigation, Conceptualization. **Emilio Martín:** Writing – review & editing, Visualization, Validation, Supervision, Formal analysis, Conceptualization. **Mohammad Jebreel:** Writing – review & editing, Validation, Resources, Project administration.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix

**Table A**  
Variable Definitions

New Abbreviation	Variable Name	Definition
INV_EFF	Investment Efficiency	Corporate investment efficiency is measured following the methodology proposed by Richardson (2006), which estimates an expected level of new investment using a firm-level regression model. The negative response from this model is interpreted as a proxy for investment inefficiency, capturing instances where firms invest less than expected, potentially indicating underinvestment or inefficient resource allocation. This baseline measure is referred to as Richardson4. A modified version, Richardson4_m, adjusts the original specification by replacing industry and year fixed effects with alternative controls specific to financial and public utility sectors on an annual basis. In addition to the Richardson-based measures, alternative proxies for investment efficiency—Biddle4 and Goodman4—are employed based on Biddle et al. (2009) and Goodman et al. (2014), respectively. These alternative models offer robust checks by modifying the dependent

(continued on next page)

Table A (continued)

New Abbreviation	Variable Name	Definition
FINT	FinTech Adoption	Log of the number of firms with FinTech-related keywords in their name at the prefecture-level city or municipality level, plus one.
ESG	Overall ESG Score	Continuous measure of a firm's overall environmental, social, and governance performance in year $t$ (from LSEG), used to test moderation effects.
CSR	CSR Strategy Score	Continuous variable indicating how well a company integrates economic, social, and environmental considerations into its decision-making processes.
SIZE	Firm Size	Natural logarithm of total assets in year $t$ .
LEV	Leverage	Ratio of total debt to total assets in year $t$ .
GROW	Sales Growth	Percentage change in total sales/revenue from year $t-1$ to year $t$ , used as a proxy for growth opportunities.
ROA	Return on Assets	Net profit after tax and extraordinary items in year $t$ , divided by total assets.
REV	Total Revenue	Total income generated by the firm through core business operations in year $t$ .
EXP	Operating Expenses	Total expenses incurred in regular business operations during year $t$ .
CAPEX	Capital Expenditures	The amount spent by the firm on long-term tangible assets such as property, plant, and equipment in year $t$ .

## Data availability

The authors do not have permission to share data.

## References

- Akerlof, G.A., 1970. The market for "lemons": quality uncertainty and the market mechanism. *Q. J. Econ.* 84 (3), 488–500. <https://doi.org/10.2307/1879431>.
- Al-Hiyari, A., Ismail, A.I., Kolsi, M.C., Kehinde, O.H., 2023. Environmental, social and governance performance (ESG) and firm investment efficiency in emerging markets: the interaction effect of board cultural diversity. *Corp. Gov. Int. J. Bus. Soc.* 23 (3), 650–673.
- Barney, J.B., 1991. Firm resources and sustained competitive advantage. *J. Manag.* 17 (1), 99–120.
- Benlemlih, M., Bitar, M., 2018. Corporate social responsibility and investment efficiency. *J. Bus. Ethics* 148, 647–671.
- Biddle, G.C., Hilary, G., Verdi, R.S., 2009. How does financial reporting quality relate to investment efficiency? *J. Account. Econ.* 48 (2–3), 112–131.
- Bilyay-Erdogan, S., Danisman, G.O., Demir, E., 2024. ESG performance and investment efficiency: The impact of information asymmetry. *J. Int. Financ. Mark. Inst. Money* 91, 101919.
- Bollen, K.A., 1996. An alternative two stage least squares (2SLS) estimator for latent variable equations. *Psychometrika* 61 (1), 109–121.
- Cai, Q., Chen, W., Wang, M., Di, K., 2025. Post-pandemic job market: an analysis of factors influencing university students' willingness for flexible employment based on SEM-ANN-fsQCA. *Humanities and Social Sciences*. Communications 12 (1), 1–18.
- Cai, Q., Chen, W., Wang, M., Di, K., 2025. The impact of self-determined efficacy on university student's environmental conservation intentions: an SEM-ANN exploration. *Environ. Dev. Sustain.* 1–38.
- Cao, Q., Zhu, T., Yu, W., 2024. ESG investment and bank efficiency: evidence from China. *Energy Econ.* 133, 107516.
- Dhiaf, M.M., Khakan, N., Atayah, O.F., Marashdeh, H., El Khoury, R., 2024. The role of FinTech for manufacturing efficiency and financial performance: in the era of industry 4.0. *J. Decis. Syst.* 33 (2), 220–241.
- Di, K., Chen, W., Shi, Q., Cai, Q., Zhang, B., 2024. Digital empowerment and win-win co-operation for green and low-carbon industrial development: analysis of regional differences based on GMM-ANN intelligence models. *J. Clean. Prod.* 445, 141332.
- Di, K., Chen, W., Shi, Q., Cai, Q., Liu, S., 2024. Analysing the impact of coupled domestic demand dynamics of green and low-carbon consumption in the market based on SEM-ANN. *J. Retail. Consum. Serv.* 79, 103856.
- Di, K., Chen, W., Zhang, X., Shi, Q., Cai, Q., Li, D., Di, Z., 2023. Regional unevenness and synergy of carbon emission reduction in China's green low-carbon circular economy. *J. Clean Prod.* 420, 138436.
- DiMaggio, P.J., Powell, W.W., 1983. The iron cage revisited: institutional isomorphism and collective rationality in organizational fields. *Am. Sociol. Rev.* 48 (2), 147–160.
- Du, J., Shi, Y., Li, W., Chen, Y., 2023. Can blockchain technology be effectively integrated into the real economy? Evidence from corporate investment efficiency. *China. China J. Account. Res.* 16 (2), 100292.
- Ellilil, N.O.D., 2022. Impact of ESG disclosure and financial reporting quality on investment efficiency. *Corp. Gov. Int. J. Bus. Soc.* 22 (5), 1094–1111.
- Freeman, R.E., 1984. *Strategic Management: A Stakeholder Approach*. Pitman Publishing.
- Gao, D., Li, S., Zhou, Y., 2025. Investment efficiency, ESG performance and corporate performance: evidence from Chinese listed enterprises. *Chin. Manag. Stud.* 19 (2), 567–599.
- Goodman, T.H., Neamtiu, M., Shroff, N., White, H.D., 2014. Management forecast quality and capital investment decisions. *Account. Rev.* 89 (1), 331–365.
- Harymawan, I., Nasih, M., Agustia, D., Putra, F.K.G., Djajadikerta, H.G., 2022. Investment efficiency and environmental, social, and governance reporting: perspective from corporate integration management. *Corp. Soc. Responsib. Environ. Manag.* 29 (5), 1186–1202.
- Heckman, J.J., 1979. Sample selection bias as a specification error. *Économ. J. Econom. Soc.* 153–161.
- Horwitz, L.I., Jones, S.A., Cerfolio, R.J., Francois, F., Greco, J., Rudy, B., Petrilli, C.M., 2021. Trends in COVID-19 risk-adjusted mortality rates. *J. Hosp. Med.* 16 (2), 90–92.
- Huang, S., 2022. Does FinTech improve the investment efficiency of enterprises? Evidence from China's small and medium-sized enterprises. *Econ. Anal. Policy* 74, 571–586.
- Huang, R., Quan, L., Luo, H., Gao, Z., Lai, X., Tang, S., 2024. Can FinTech promote enterprise cross-region investment?—evidence from China. *Int. Rev. Econ. & Financ.* 96, 103524.
- Jiang, Q., Zhang, C., Wei, Q., 2025. Digital technology adoption and enterprise investment efficiency. *Financ. Res. Lett.* 72, 106623.
- Lee, C.C., Li, X., Yu, C.H., Zhao, J., 2021. Does FinTech innovation improve bank efficiency? Evidence from China's banking industry. *Int. Rev. Econ. & Financ.* 74, 468–483.
- Lian, Y., Weng, X., 2024. ESG performance and investment efficiency. *Financ. Res. Lett.* 62, 105084.
- Lin, Y., Yan, X., Yang, X., 2023. Digital finance and enterprise investment efficiency in China. *Int. Rev. Financ. Anal.* 90, 102929.
- Liu, J., 2024. Analyzing the Co-movement of FinTech market efficiency and oil Resource efficiency: An Input-Output study. *Resour. Policy* 90, 104668.
- Lv, P., Xiong, H., 2022. Can FinTech improve corporate investment efficiency? Evidence from China. *Res. Int. Bus. Financ.* 60, 101571.
- Maiyarni, R., Utama, S., Djakman, C.D., Mita, A.F., 2024. How does financial reporting quality mediate ESG performance to investment efficiency? *Int. J. Ethics Syst. Organisation for Economic Co-operation and Development (OECD)*, 2021. OECD economic outlook. OECD Publishing. <https://doi.org/10.1787/edfca02-en>.
- Pandey, D.K., 2025a. "FinTech literature reviews: a hybrid approach". *Financ. Res. Lett.* 79, 107249. <https://doi.org/10.1016/j.frl.2025.107249>.
- Pandey, D.K., 2025c. "FinTech adoption literature: current state and future directions". Trends and Challenges of Electronic Finance. Springer Nature Singapore, Singapore, pp. 179–215. [https://doi.org/10.1007/978-981-96-3304-3\\_11](https://doi.org/10.1007/978-981-96-3304-3_11).
- Pandey, D.K., 2025b. "FinTech and small and medium enterprises: current state and future directions". *TQM J.* <https://doi.org/10.1108/tqm-07-2024-0259>.
- Qi, Y., Ouyang, L., Yu, Y., 2024. The impact of FinTech adoption on corporate investment: Evidence from China. *Financ. Res. Lett.* 67, 105929.
- Rahman, M.J., Rana, T., Zhu, H., Zhuge, L., 2025. The relationship between ESG disclosure, financial reporting quality, and investment efficiency. *Environmental, Social and Governance Accounting and Auditing*. Routledge, pp. 171–188.
- Richardson, S., 2006. Over-investment of free cash flow. *Rev. Account. Stud.* 11, 159–189.
- Siddik, A.B., Rahman, M.N., Yong, L., 2023. Do FinTech adoption and financial literacy improve corporate sustainability performance? The mediating role of access to finance. *J. Clean. Prod.* 421, 137658.
- Sun, T., Di, K., Cai, Q., Du, H., 2025. The study of the random evolutionary game model and policy effects of carbon information disclosure by Chinese listed companies. *J. Environ. Manag.* 391, 126369.
- Sun, T., Di, K., Shi, Q., Hu, J., Zhang, X., 2024. Study on the development path of low-carbon retail clusters empowered by digital empowerment. *J. Retail. Consum. Serv.* 81, 104006.
- Tang, S., Chen, Z., Chen, J., Quan, L., Guan, K., 2023. Does FinTech promote corporate competitiveness? Evidence from China. *Financ. Res. Lett.* 58, 104660.
- Wang, Y., Chen, L., Zhuang, J., 2024. Research on ESG Investment Efficiency Regulation from the Perspective of Reciprocity and Evolutionary Game. *Comput. Econ.* 64 (3), 1665–1695.
- Wang, J., Qiao, L., Zhu, G., Di, K., Zhang, X., 2025. Research on the driving factors and impact mechanisms of green new quality productive forces in high-tech retail enterprises under China's Dual Carbon Goals. *J. Retail. Consum. Serv.* 82, 104092.

- World Bank, 2022. World development report 2022: Finance for an equitable recovery. World Bank. <https://doi.org/10.1596/978-1-4648-1730-4>.
- Xue, H., Cai, M., Liu, B., Di, K., Hu, J., 2025. Sustainable development through digital innovation: Unveiling the impact of big data comprehensive experimental zones on energy utilization efficiency. *Sustain. Dev.* 33 (1), 177–189.
- Yu, X., Xiao, K., 2022. Does ESG performance affect firm value? Evidence from a new ESG-scoring approach for Chinese enterprises. *sustainability* 14 (24), 16940.
- Zhao, T., Shi, Q., Zhang, X., Zhang, T., 2024. Decoding green food safety information dependency in the digital era: an intelligent validation using SEM-ANN framework. *J. Retail. Consum. Serv.* 79, 103886.

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