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DOES DIGITAL FINANCIAL INCLUSION IMPACT ESG PERFORMANCE IN ISLAMIC AND CONVENTIONAL FINANCIAL INSTITUTIONS? A GLOBAL EVIDENCE

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ABSTRACT

This study investigates the impact of digital financial inclusion on corporate ESG performance using a global sample of 660 conventional and Islamic institutions from 2010 to 2022. The study reveals that digital financial inclusion can significantly promote corporate ESG performance. What sets this study apart is its use of the novel methodology of fixed effects model and Methods of Moments Quantile Regression (MMQR) to empirically identify how digital financial inclusion affects corporate ESG performance from lower to higher quantiles (0.1 to 0.9). Further, the analysis using 1st and 2nd SLS shows that digital financial inclusion has a more pronounced impact on Islamic banks' ESG scores, mainly when involved in the high implementation of digitalization. These significant results are assured by legitimacy and stakeholder theories. ESG factors have been significantly affected by adopting modern digital applications and platforms in regulated industries of Islamic institutions. Sub-Sample analysis of financial institutions and heterogeneity analysis of more and less board independence and board size significantly impact implementing digital financial inclusion and ESG performance, instilling the need to mitigate banks' risks by disclosing non-financial information and resolving agency conflicts among stakeholders aimed at investing in sustainable green projects. Finally, our results remain robust after addressing endogeneity issues and conducting robustness checks, offering new insights into the evolving digital financial inclusion and ESG performance.

Keywords: Digital financial inclusion, ESG disclosure, Agency and signaling theory, Islamic and financial institutions.
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I. INTRODUCTION

The "Who Cares Wins (WCW)" initiative, coined by the UN Secretary-General and UN Global Compact in 2004, has profoundly shaped financial perceptions, providing a compass for environmental, social, and governance (ESG) disclosure among stakeholders involved in investment activities. ESG has become increasingly significant in recent years, particularly in developing sustainable strategies. Investors' social consciousness has dramatically heightened due to multiple financial, social, and environmental concerns. According to international agencies and bodies, the value of ESG assets grew substantially from $22.8 trillion to $30.6 trillion from 2016 to 2018 (Albitar et al., 2020). Further, Bloomberg anticipates a subsequent upsurge, predicting the value of ESG assets to be $53 trillion by 2025 (Alda, 2021). Meanwhile, financial institutions and governments are becoming more focused on developing a pollution-free environment, implementing socially responsible policies, and promoting stakeholder openness (Almeyda & Darmansya, 2019). ESG investments encompass a wide range of issues, including addressing environmental concerns through energy transitions, reducing carbon emissions, addressing social issues such as customer satisfaction and human rights, and ensuring good governance through rules that identify the responsibilities of stakeholders within financial institutions (Amel-Zadeh & Serafeim, 2018; Amuakwa-Mensah & Näsström, 2022).

ESG disclosure has been inculcated from the perspectives of two fundamental trends studied in past literature (Alshehhi et al., 2018; Amor-Esteban et al., 2019). Earlier studies focus on the ESG disclosure and economic consequences and aim to reduce market information asymmetry, financial performance, stock returns, risk volatility, and earnings management strategies (Arouri et al., 2019; Atif & Ali, 2021). Few studies have illustrated the role of ESG disclosure on corporate governance indicators such as CEO power, ownership structure, gender diversity, corporate financial decisions (cost of capital finance, dividend payout), and board structure (Attig, 2024; Aydin & Cavdar, 2015). However, the development of fintech financial inclusion on ESG disclosure has been overlooked (Galeone et al., 2024). This study attempts to fill this gap by explicitly implementing digital financial inclusion in financial and Islamic bank institutions regarding ESG disclosure.

Financial inclusion presupposes that everyone involved in financial intermediation would have complete access to all available financial instruments and sources of information (J. Li et al., 2020). This leads to a decrease in the cost of financing and of asymmetric information, as well as an increase in employment and financial stability (Wang et al., 2023). The incorporation and utilization of digital inclusion, which entails the integration of digital technology and financial services, plays an essential role in addressing the concerns of financial and Islamic banking institutions (Ahluwalia et al., 2020). Using DFI instruments and applications inculcates different financial functions, resulting in an influential role in Islamic banks' operations. As a result, the adoption and application of financial tools such as innovative sukuk platforms, Shariah-compliant fintech apps, or zakat and waqf crowdfunding technologies are not merely digitized versions of conventional finance tools but are designed to meet unique religious, legal, and ethical requirements. In contrast, DFI in conventional banks typically focuses on efficiency, automation, and customer convenience without the added layer of Shariah governance (Gao et al., 2022).

Islamic banks separately evaluate financial principles, governing mechanisms, and regulatory requirements, which differentiate from conventional banks. These banks operate under the conditions of Shariah, revolve around interest, transactions based on speculation, and unethical investments. Whereas these banks rely on a profit-loss sharing perspective, Ijara financing inherently shapes financial inclusion and ESG disclosure (Rabbani, 2022: Rabbani et al., 2022). Such differences allow banks to integrate DFI-related mechanisms that report ESG-based transparency. Additionally, such DFI applications are implemented in Islamic banks with Sharia technologies that ensure ethical and religious principles. Islamic finance adopts DFI applications, such as blockchain and crowdfunding, which are more important for promoting financial inclusion and maintaining governance and compliance. Based on these consequences, the role of DFI on ESG disclosure in Islamic banks may differ from that of conventional banks (Gao et al., 2022; Klapper et al., 2016).

Overall, Abedifar et al. (2013), focused on DFI and ESG specifically for conventional banks while neglecting operational factors of Islamic banks. Investors and policymakers are distinctly aligned in digital financial policies for operational and ethical principles. This study also initiates the interpolation of DFI and ESG in Islamic and conventional banks. To streamline the financial procedures and practices, adopting such techniques enables financial institutions to enhance management strategies and minimize agency conflicts for stakeholders and managers (Pang et al., 2022). DFI enables banks to implement transaction processes by using innovative technological applications with increased development of financial working capital and practical insights into financial standings (Yee et al., 2018).

Because of modern digital services, DFI aims to fulfill financial and Islamic banks' needs by promoting transparency and accountability and achieving sustainable development goals for banks (Gao et al., 2022; Klapper et al., 2016). Likewise, a study posits that DFI increases data analytics and integrated reporting capabilities, which gives positive signals to the general public to efficiently monitor and access financial and non-financial information, including ESG disclosure (Barik & Sharma, 2019). Similarly, past literature has illustrated that DFI facilitates green, sustainable practices and development for financial institutions and Islamic banks to adopt accessible investment methods for customers and the general public (Bertay et al., 2013). This enhanced growth of green sustainable practices provides environmental and social benefits. Thus, in the literature, results are dichotomous. Few studies have provided a favorable impact of digital financial inclusion on companies (Ahamed & Mallick, 2019; Alareeni & Hamdan, 2020). Many studies illustrate the negative impact (Abedifar et al., 2013). The role of implementing digital inclusion and payments with financial institutions and Islamic banks in global countries has been ignored. Thus, this research intends to provide empirical evidence on DFI's direct and indirect impact on corporate ESG disclosure in global nations.

This study entails financial and Islamic banks of global countries taken as a sample. The results reveal positive and significant outcomes, illustrating the role of DFI in banks' ESG information that reduces the asymmetry problem, agency costs, and revokes stakeholder conflict (Hassan et al., 2019). Moreover, a deeper

investigation of this underlying relationship gave positive signals to the market with the support of the signaling theory for global countries. Notably, the impact of DFI on ESG disclosure has been more pronounced with the results of the first and second stages of GMM, giving significant outcomes. This observation underscores the transformative potential of digital financial inclusion in fostering sustainable practices and promoting responsible corporate stewardship across diverse contexts.

This study provides a subsequent contribution to the prior literature, which is explained in this paper. Firstly, this adds to the effects of DFI on sustainable corporate activities. (Banna, 2020). Secondly, this study focuses on ESG disclosure, primarily financial and Islamic institutions of global countries, from 2010 to 2022. In past literature, DFI's direct and indirect effects on ESG performance have been seen with the underlying mechanism, such as internal controls in OIC countries (Rashid et al., 2017; Vo et al., 2021). However, no study entails this relationship nexus between global banks and financial institutions. Further, this study employs a significant proxy of DFI through the FFI index for Islamic banks, which was coined by Ahamed & Mallick (2019) and Demirgüç-Kunt & Huizinga (2010). In the past, literature followed other sources such as the IMP, the World Bank, etc. Last, this study adopts a novel methodological technique, the Method of Moment Quantile Regression (MMQR), developed by the 1st and 2nd stage GMM for robustness analysis. The findings are consistent with our primary regression.

The remaining paper is summarized: The literature and hypothesis development are discussed in the next section. Research data, sampling techniques, description, and econometric equations are elaborated in Section 3. Empirical results and discussion are written in Section 4, and Section 5 includes a conclusion, policy implications, and future research.

II. LITERATURE REVIEW AND HYPOTHESIS

Digital financial inclusion has been beneficial for banks and financial organizations. Banks experience a rise in customer engagement, resulting in increased savings. This allows them to invest in new technologies, creating new job opportunities. Additionally, banks utilize financial technologies to acquire diverse information on creditors, which allows them to venture into new business opportunities. A study by Prasad et al. (2010) argues that retail financing costs are lower than wholesale sources. The higher degree of inclusivity allows banks to engage in deposit and lending activities with socioeconomically underprivileged groups, which helps mitigate the risk of pro-cyclicality for banks (Han & Melecky, 2013). The study of Smaoui et al. (2020) demonstrates the positive significance of financial inclusion on stable growth deposits for financial systems, resulting in external debts and decreases in equity. Banks and financial institutions find a positive role in strategic risk-taking, contributing to the right financing mix and having substantial liquidity (Ayadi & De Groen, 2014) and market power (Ahmed et al., 2020).

Further, past studies discuss the positive association between DFI and economic factors such as financial risk, reduced bank risk-taking, and improved investment efficiency with successful business sustainable practices aimed at reducing fraud and corruption (Huang et al., 2022; X. Wang et al., 2022). With the advancement of

financial inclusion, banks follow market dynamics while implementing modern technological strategies for ongoing cultural improvement. Similarly, a study of Mu et al. (2023) provides strong support for including innovative technology for financial and non-financial firms in China. The findings suggest a favorable impact of digital financial inclusion on financial constraints and more ownership structure. Another study by Giannopoulos et al. (2022) reveals the underlying mechanism of government subsidies, which increase disclosure sustainability capabilities and innovative firm performance.

In addition, the non-linear relationship of DFI and firm-level innovation has been documented, which shows different intensity factors that impact the rapid growth of sustainability practices (Sun et al., 2024). Another study by Suhrab et al. (2024) identifies that DFI reduces environmental regulations on technology innovation. The mitigating role of DFI in the relationship is more pronounced for firms with a lack of access to financial resources and those operating in sensitive industries.

Past studies focus on the nexus between DFI and green development, but few authors support a positive influence (Allen et al., 2016; Beck et al., 2007; Kim et al., 2020), and others (Neaime & Gaysset, 2018; Alfadli & Rjoub, 2020) claim the opposite. Due to the development of sustainable projects, an eco-friendly environment has been initiated, which has promoted positive signals to the market by considering environmental factors. Banna (2020) find that green innovation reduces financial constraints while increasing R&D investments in banks, especially for OIC economies. Another author reveals that modern innovation increases quantity and quality for sustainable strategies (Banna & Alam, 2020). Berger et al. (2019) illustrate that DFI supports banks in discharging their social responsibilities by mitigating information asymmetry among financial institutions. Concerning corporate environmental responsibility, the recent work of Liu et al. (2024) posits that the development of regional digital finance influences corporate environmental performance. Financing efficiency and innovation serve as a mechanism to support the relationship between DFI and corporate environmental performance (Mahmood Ahmad et al., 2023; Alam et al., 2025).

Liu et al. (2024) suggest a promotion effect of DFI on corporate ESG disclosures, highlighting the influencing mechanisms of coverage breadth, depth of use, and level of digitalization (Billah, 2021). In contrast, Hao et al. (2024) propose a U-shaped association between DFI and corporate sustainability performance. They further argue that this relationship is mediated by financial volatility and sales growth, suggesting that DFI can positively and negatively affect corporate sustainability performance (Hui et al., 2023).

Implementing digital financial inclusion has benefited businesses by facilitating access to information, making ESG disclosure practices easier between investors and firms, and reducing information asymmetry (S. Chen & Zhang, 2021). Signaling theory also supports the argument that adopting digital financial inclusion decreases information asymmetry among stakeholders by allowing firms to provide positive signals to externals, ultimately reducing stock uncertainty risk (Xiang et al., 2017). A positive perception of the organization is fostered by its ESG disclosure, which signals stakeholders that the firms are not solely focused on profit and have no other agenda (Munir Ahmad et al., 2019). They continually

acquire and maintain their reputation, actively participate in environmental, social, and governance (ESG) initiatives, and provide positive ESG information, all of which facilitate its non-financial disclosure (Y. Chen & Bellavitis, 2020). However, the advancement of digital financial inclusion aids in reducing information asymmetries between companies and financial institutions (Azmi et al., 2021). This further allows external institutions to evaluate the financial resources and reduces the level of risk in the financial and banking sectors by using different digital technologies. To achieve sustainable development practices, firms disclose more ESG information and convey positive signals to the market, resulting in enhanced firms' credit finance ability (Luo, 2022). By taking advantage of green ESG investments from investors, firms obtain positive responses by implementing digital financial inclusion and engaging in more ESG activities (Shanaev & Ghimire, 2022). By leveraging digital financial tools, Islamic banks signal their commitment to financial inclusion, sustainability, and ethical governance, enhancing investor confidence and market stability. Unlike conventional banks, which primarily use DFI for efficiency and market expansion, Islamic banks employ it to reinforce their compliance with ESG principles, particularly in areas such as green finance, ethical investments, and financial inclusion for underprivileged communities.

The expansion of digital financial inclusion facilitates managers and policymakers to implement sustainable development strategies that mitigate myopia, strengthening firms' capacity to manage risks (Gregory, 2022). According to the upper echelon theory proposed by Hambrick & Mason (1984), the progress of digital financial inclusion enables managers to comprehend and endorse ESG information. Further, ESG social responsibility strategies are achieved by stakeholder demands, determining a favorable external environment for business development to mitigate potential risks (Kim et al., 2022), and consequently encouraging corporate ESG engagement in information disclosure. In addition, the advancement of digital financial inclusion has enriched corporate financing (Ding et al., 2022), decreased the expenses associated with obtaining external funding, made it easier to access additional capital (Huang et al., 2022), provided to improve the market competitiveness of businesses, and raised corporate value (Aabo & Giorici, 2023). This theory suggests that leadership characteristics, regulatory frameworks, and strategic priorities influence decision-making in financial institutions. Since Islamic banks prioritize Shariah compliance, DFI adoption in these institutions must align with Shariah-compliant financial technologies such as Islamic FinTech, blockchain for transparent transactions, and ethical AI-driven investment screening. The integration of DFI in Islamic banks enhances ESG disclosure by promoting transparency, reducing information asymmetry, and ensuring ethical financial practices, which are more rigorously enforced compared to conventional banks.

A study by Yang et al. (2022) suggests that Islamic Fintech in GCC countries explore environmental regulations using digital technologies. Other studies have analyzed Islamic banks' use of technology-based fintech. A study by Ali et al. (2019) suggests that Malaysia analyze the importance of digital Fintech in growing the reputation of Islamic banks. Another study by Rabbani et al. (2020) utilizes blockchain technologies to ensure the principles of Sharia compliance, which is most appropriate for the unbanked customer population and small-scale

businesses. Few studies focus on a systematic literature review in technology-based ESG banking disclosure. Rabbani et al. (2021) conduct a meta-analysis of 16 studies on the association between cryptocurrencies and blockchain in financial institutions. A study by Hassan et al. (2020) collects an association related to Islamic fintech and provides regulatory frameworks concerning financial institutions. Consequently, this has enabled companies to have more significant financial resources and income, thereby enhancing the value of shareholders' investments (Cui et al., 2022). This, in turn, facilitates businesses' active participation in ESG activities and encourages them to adopt more ESG practices, such as disclosing ESG information.

H1: Digital financial inclusion significantly influences Islamic and conventional banks' ESG disclosure

H2: Due to intensity and engagement with technology, digital financial inclusion is more significant at individual sub-samples of financial institutions

III. METHODOLOGY

3.1. Data and Sample Size

The data used in this study cover 660 Islamic and conventional banks worldwide (Australia, Argentina, USA, UK, etc) from 2010 to 2022. More specifically, individual financial institutions are from four different groups, 324 banks (43 Islamic Vs 281 conventional), 122 investments, 143 insurances, and 71 others. The study uses a distinct metric for assessing environmental quality: banks' ESG disclosure. Data has been collected from different sources. The data on the ESG score has been extracted from Refinitiv Eikon DataStream. Digital financial inclusion is a proxy from the Global Findex Survey. Specifically, we construct DFI as a binary variable based on the presence and intensity of digital financial services, such as mobile banking, fintech adoption, and digital payments within a country. If institutions and banks use such technologies in business transactions, it denotes 1; otherwise, it is 0. This classification follows existing literature that uses similar binary or index-based measures to assess financial inclusion at the national level. To integrate this with firm-level ESG disclosure data, we adopt a multi-dimensional linkage approach where firms operating in countries with higher DFI adoption are assumed to have greater exposure to digital financial ecosystems. This exposure facilitates improved financial reporting, transparency, and accessibility to sustainable financial products, influencing firms' ESG disclosure practices. Further, control variables such as Board diversity, which are measured through educational background, expertise, or nationality, have been examined by enhancing board effectiveness and firms' perspectives. Diverse boards are more likely to consider stakeholder interests, which can positively influence ESG strategies and disclosure transparency. Gender-diverse boards and independent members have been found to improve ethical oversight and enhance attention to non-financial performance indicators such as environmental sustainability and reducing agency conflicts. Women directors are often associated with stronger risk aversion and higher ESG awareness. CO_2 emissions are a key indicator of a firm's environmental footprint and are often used as a proxy for environmental risk. Including CO_2 emissions as a control variable allows the model to account

for firms' exposure to climate-related financial and reputational risks, which can directly affect ESG ratings and disclosure behavior (Arouri et al., 2019; Atif & Ali, 2021). Table 1 explains the control variables further.

Table 1.
Variable Description

Variables		Description	Source
ESG	Environmental, Social, and Governance	database	Refinitiv
DFI	Digital financial inclusion	If a mobile phone makes payments, otherwise 0	GFS
BD	Board Diversity	composition of a company's board of directors by including a variety of individuals	Refinitiv
GD	Gender Diversity	Composition of a company board of directors by females to males	-
IND	Independent	The ratio of independent to total directors on a company's board	-
BS	Board Size	Natural logarithm of the total directors on the company's board.	-
CO2	Co2 Emissions	Total emissions	WDI

3.2. Econometric Equation

To mitigate the presence of heteroscedasticity, we applied a natural logarithm transformation to each of the indicators. Our model is written as:

$$ESG_{it} = \beta_0 + \beta_1(DFI_{it}) + \beta_2(BD_{it}) + \beta_3(GD_{it}) + \beta_4(IND_{it}) + \beta_5(BS_{it}) + \beta_6(Co2_{it}) + €_{it} \quad (1)$$

where ESG is a dependent variable, DFI (digital financial inclusion) is an independent variable, and others are controls. The parameters to be estimated are β_1 to $\beta_{6,}$ the error term is represented by $€_{it}$, and nations and periods are denoted by the subscripts i and t, respectively.

For a streamlined regression, this study uses the MMQR model by Machado & Silva (2019). This model allows the individual consequences to ripple through the whole distribution while exhibiting covariance effects under constrained heterogeneity.

$$ESG_{it}(\tau I\gamma_i, \delta_t, X_{i,t}) = \varphi_i + \lambda_{1,\tau}DFI_{i,t} + \lambda_{2,\tau}BD_{i,t} + \lambda_{3,\tau}GD_{i,t} + \lambda_{4,\tau}IND_{i,t} + \lambda_{5,\tau}BS_{i,t} + \lambda_{6,\tau}CO2_{i,t} + v_{\tau,i,t} \quad (2)$$

3.3. Methodology

Before estimating the baseline regression, this study utilizes preliminary diagnostics. The Breusch-Pagan test indicate the presence of heteroskedasticity in the residuals. This violates the homoskedasticity assumption of the classical

OLS, implying that standard errors may be biased, and hence, robust estimation techniques are necessary. Conversely, the Chow test is statistically insignificant, suggesting no structural break between the compared groups or periods. This implies that the relationship between the dependent and independent variables does not differ significantly across the specified subgroups. The significant value of the Hausman test denotes that the Fixed Effects model is more appropriate than the Random Effects model, confirming that the unobserved individual heterogeneity is correlated with the regressors. The Durbin-Wu-Hausman (DWH) test has been applied to address potential endogeneity, but the value is not statistically significant.

The novel technique of MMQR regression is employed in the analysis because it thoroughly captures the relationship between variables by evaluating several quantiles of the dependent variable rather than solely focusing on the mean. This technique is especially effective in datasets where the impact of independent variables fluctuates throughout the distribution or when there are outliers, as it is more robust to these abnormalities. MMQR is adaptable, enabling the representation of non-linear connections and accommodating input from different underlying processes or distributions. This characteristic renders it particularly important in disciplines such as economics, finance, and social sciences, where comprehending relationship fluctuations across various distribution segments is paramount. MMQR generally provides a more comprehensive and sophisticated analysis than conventional regression approaches.

Furthermore, MMQR is proficient in addressing heteroscedasticity, which refers to the varying levels of variability in the dependent variable across different levels of an independent variable. Traditional regression assumes homoscedasticity, meaning that the variance of the residuals is constant across all levels of the predictor variable. However, MMQR allows for heteroscedasticity, suggesting that the variance of the residuals can vary across different quantiles of the predictor variable. This provides a more precise and accurate way to depict the relationship between variables under these conditions.

IV. RESULTS AND ANALYSIS

4.1. Descriptive Statistics

Table 2 shows the summary statistics of all variables, including mean, standard deviation, minimum, and maximum values. The mean value of ESG depicts that Islamic and conventional banks had low ESG problems during the sample period. Independent variable DFI shows significant means and standard deviation results of 0.6 and 0.49. At the same time, the minimum and maximum values are between 0 and 1. ROA, a firm-level control variable, contains an average of -4.328 and 1.106 dispersed values, having -11.51 and -0.519 smaller and greater values. Board size (BS) averages 2.419 and 0.327, and independent board members are 4.037 and 0.53. The minimum and maximum values are 0.693 and 3.714, but the independent board members' values are 1.56 and 4.605. The overall results illustrate no outliers, and all variables are within range.

Table 2.
Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ESG	8644	3.791	.514	.425	4.561
DFI	8644	.6	.49	0	1
ROA	8644	-4.328	1.106	-11.513	-.519
BS	8644	2.419	.327	.693	3.714
IND	8644	4.037	.53	1.56	4.605
CO2	8644	10.079	2.073	1.482	17.82
GD	8644	2.978	.558	.94	4.287
BD	8644	2.978	.558	.94	4.287

4.2. Baseline Analysis (Fixed Effect Model)

Table 3 provides results on the relations between digital financial inclusion and ESG disclosure along with other controls of financial institutions. A fixed effect model is selected as the baseline regression based on the Hausman test statistic (P=0.05). The results show that digital financial inclusion has a positive and significant effect on the ESG score (1.159, P<0.05). This means that implementation of digital financial services is assocaited with better ESG performance. This positive association implies that digital financial inclusion not only enhances financial accessibility and efficiency but also supports broader sustainability goals. It may enable firms, especially in developing economies, to adopt cleaner technologies, improve transparency, and engage more inclusively with stakeholders, thereby strengthening their ESG profiles. The significant coefficient affirms that digital financial inclusion plays an important enabling role in fostering responsible business practices and sustainable development. Past studies also document similar results (Shakil, 2021; Xiang et al., 2017; Irfan et al., 2022). From Table 3, we may also note that other controls also significantly influence ESG scores (Iheanachor & Umukoro, 2022; Hou et al., 2023).

Table 3.
Regression Analysis

	(1)
VARIABLES	**ESG**
DFI	1.159***
	(2.45)
BD	0.047***
	(2.36)
CO2	0.27*
	(1.38)
IND	0.158***
	(10.33)
BS	0.283***
	(4.32)
ROA	5.99
	(0.87)

Table 3.
Regression Analysis (Continued)

	(1)
VARIABLES	**ESG**
Constant	49.33***
	(35.77)
Observations	3404
R-squared	0.39
Number of id	462

Notes: t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4.3. Regression Test (MMQR Model)

Table 4 presents the results of MMQR regression to evaluate the role of digital financial inclusion on ESG disclosure. We may note that DFI is significant and positively impacts ESG from lower to higher quantiles. The results are consistent with earlier literature (Wong et al., 2018; Xin et al., 2022; Yang & Li, 2023). Furthermore, those Islamic banks implementing digital financial infrastructure have created emission-free environments to transparently monitor social and governance concerns (Ren et al., 2023). Banks facilitate positive signals while implementing financial technology, allowing investors to disclose ESG information about Islamic institutions in global countries.

ROA and other control variables illustrate significant results as ROA is negatively insignificant for lower quantiles but remains significant from (q=0.7 to 0.9). Other variables are similar to past studies (Baker et al., 2021; Gregory, 2022; Huang et al., 2022).

Table 4.
Panel MMQR Regression

Variables	Scale	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
DFI	0.004	0.029***	0.027***	0.025***	0.023***	0.022***	0.02***	0.018***	0.017**	0.05*
ROA	-0.07***	-0.00	-0.05	-0.02	-0.01	-0.03	-0.05	-0.06***	-.08***	-0.01***
BS	0.08	-0.07***	-0.06***	-0.06***	-0.06***	-0.07***	-0.05***	-0.06***	-.05***	-0.04***
IND	-.313***	0.228***	0.212***	0.198***	0.185***	0.174***	0.141***	0.151***	.142***	0.130***
CO2	-.110***	-.233***	0.027***	0.023***	0.018***	0.014***	0.009*	0.006	0.003	0.009
GD	0.033***	0.015***	0.094***	0.084***	0.069***	0.058***	0.04***	0.033*	0.028	0.011

Note: ***, **, and *at 1%, 5%, and 10%, and St. Error are in ().

4.4. Regression Analysis (Sub-Sample)

Sub-sampling permits researchers to examine whether the impacts of DFI (or other variables) vary different groups of financial institutions. This methodology can uncover diversity in the data, indicating that the influence of DFI may differ based on the distinct attributes of the institutions under study. The impact of DFI can vary among different financial institutions due to its heterogeneity. Smaller or regional banks, for instance, may depend more on domestic financial infrastructure, thus

making DFI more crucial in elucidating their performance or behavior. On the other hand, central or global banks may have various funding options, making them less susceptible to the impact of DFI.

Regulatory and market variances might cause variations in the role of DFI, as sub-samples may exhibit inequalities in regulatory regimes or market conditions that either enhance or reduce its impact. Financial institutions operating in less developed markets may rely more on local financial resources, making DFIs more crucial. By limiting the scope to smaller samples, the analysis could decrease irrelevant information in the data, resulting in a more distinct and statistically significant correlation between DFI and the outcome variables. This phenomenon could arise due to the possibility that sub-samples are more likely to capture more homogeneous groupings, resulting in more consistent underlying dynamics.

Table 5 shows the results of individual financial institutions categorized into four different groups, 324 banks (43 Islamic Vs 281 conventional), 122 investments, 143 insurance, and 71 others. The results of DFI have a positive and significant relation for both Islamic and conventional banks, as given in columns 1 and 2 respectively, which is in line with other studies (Weber et al., 2014; Wong et al., 2018). Financial inclusion enhances adequate infrastructure for a country; financial institutions have created investment opportunities across different groups.

Similarly, environmental regulations can be embedded in environmental sustainability practices, which vary in Islamic banks (Le et al., 2021). The digital revolution has led to significant changes in the market structure and compelled financial services firms to reevaluate their models and strategies, hence upsetting the established trends utilized by intermediaries (Gong & Ribiere, 2021). The bank-customer relationship model is being restructured due to significant developments in consumer habits. These developments are driven by the need of clients for immediate, simple, and accessible solutions when it comes to buying and employing banking services (Wang et al., 2021). Consequently, there is a growing reliance on digital technologies in the transmission of financial services, such as digital FinTech. Specifically, as revealed in the results, most intermediaries offer payment services to their customers via mobile applications and asset management services through digital platforms (Le, 2021).

In a nutshell, new technologies are going to have a significant impact on the way banks conduct internal operations and interact with customers. Regarding managing internal resources, incorporating technological tools and robotics to carry out repetitive tasks (such as assembling and validating information for a loan application) drastically decreases the time needed to complete records (Luo et al., 2023). This enables employees to concentrate on more intricate operations that improve human interaction and subjective input in decision-making. Incorporating more sophisticated technologies in the bank may assist in meeting regulatory and operational risk control standards (Lv & Xiong, 2022).

Other control variables, e.g., board diversity, are significantly related to ESG disclosure for investment institutions. However, for other sectors, there remains no significant effect is documented. The results are also similar to past studies (Tekin, 2025; Thakor, 2020; Liu et al. 2023). Independent members of the ownership structure positively influence ESG disclosure (0.008, P=0.05). ROA also plays a significant role. To conclude, the results are consistent with our main regression findings.

Table 5.
Sub-sample Analysis

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Islamic	**Conventional**	**Investment**	**insurance**	**Other**
DFI	0.105***	-0.026	3.172**	1.754*	1.269
	(3.524)	(-1.101)	(2.46)	(1.85)	(0.75)
BD	0.001	-0.002	0.084*	-0.024	-0.099
	(1.133)	(-1.237)	(1.888)	(-0.556)	(-1.275)
CO2	0.000*	0.000***	0.000**	0.000	0.000
	(1.803)	(3.961)	(2.061)	(0.708)	(0.645)
IND	0.008***	0.003***	0.178***	0.066**	0.257***
	(7.570)	(4.222)	(5.071)	(2.191)	(4.235)
BS	0.069***	-0.012***	0.46**	0.51***	0.08
	(17.429)	(-3.914)	(-2.296)	(-4.197)	(-0.318)
ROA	4.401***	1.964**	7.87	55.82***	36.61
	(2.854)	(2.178)	(-1.02)	(-3.08)	(1.65)
Constant	1.541***	4.028***	41.802***	58.754***	29.838***
	(9.740)	(37.307)	(12.278)	(19.517)	(5.465)
Observations	1346	306	609	824	264
R-squared	0.421	0.433	0.472	0.369	0.478

Notes: t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4.5. Endogeneity Analysis

For the lag of DFI to serve as an excellent instrumental variable (IV), it must exhibit a significant association with the endogenous explanatory variable, which in this case is Financial Technology. The study must establish the statistical significance of the lagged DFI in predicting FI. Typically, this is accomplished through studying the initial regression. The main objective of the initial phase in 2SLS is to acquire the estimated values of the endogenous variable (FI) by utilizing the instrumental variable(s). If the authors erroneously utilize this step to determine the ESG score rather than the FI, this constitutes a significant technical flaw. The appropriate methodology would entail utilizing the lagged DFI to forecast FI and subsequently employing the predicted values in the second stage to evaluate the association between FI and the dependent variable. If the initial stage is inappropriately utilized to forecast the primary variable, the subsequent stage will not employ accurate instruments. This error would result in distorted estimates since the second stage fails to accurately account for FI's endogeneity. The primary goal of the 2SLS method, which aims to tackle endogeneity, would ultimately be deemed ineffective. To obtain the fitted values of FI, the correct strategy would be first to regress FI on lagged DFI. Subsequently, the fitted values serve as the independent variable in the second regression stage for forecasting the ESG score. This procedure guarantees that the endogeneity of FI does not influence the calculated correlation between FI and ESG.

To accurately assess the influence of digital finance, it is necessary to address any potential endogeneity issues in the econometric model. In our empirical

research, we employ the instrumental variable (IV) technique to address this issue, following the methodology of Wang, Qiu, Sader, Huang, & Shang (2023). Initially, a lag of DFI has been utilized as an instrument. Table 6 displays the results obtained from the estimation using the two-stage least squares (2SLS) method. The results from the Table are consistent with our primary estimation.

Table 6.
Robustness Test

Variables	(1) DFI 1st stage	(2) ESG 2nd Stage
DFI		0.041***
IV (l. DFI)	0.0275***	
ROA	-0.032***	-0.031***
BS	0.008	0.006
IND	0.102***	0.106***
CO2	0.055***	0.055***
BD	0.005***	0.004***
C	2.768***	2.718***
OBS	8644	8644
R-sq	0.99	0.25
And. canon	2343.78	2290.1***

Note: *** p<.01, ** p<.05, * p<.1

4.6. Heterogeneity Analysis

Table 7 represents the heterogeneity test for IND and board size to check the impact of digital financial inclusion on ESG performance. Regarding high board independence, FI positively and significantly impacts sustainability performance. However, for less board independence, it turns insignificant. Perhaps, independent directors have the authority to implement digital financial technology in bank operations and disclose ESG information for resolving the agency problem among stakeholders. Board diversity also has a significant impact on ESG disclosure for both high independence (B=0.320, P<0.05), and low independence (B=0.268, P<0.05). Carbon emissions do not affect ESG due in high independence sample but positively impact ESG performance with less board independence (B=0.000, P<0.05). Board size and ROA also positively influence ESG sustainability investments for both samples.

Board size has also been employed for heterogeneity analysis to examine the relationship between DFI-ESG performance. Digital financial inclusion has a positive effect on ESG regardless of board size. Board diversity has a positive and significant impact for both samples (B=0.139, 0.341, P<0.05). Similar results are documented for CO2 emissions and board independence.

Table 7.
Board Independence and Board Size

VARIABLES	(1)	(2)	(1)	(2)
	High	**Low**	**High**	**Low**
DFI	3.148***	-7.320	1.601***	1.580***
	(3.99)	(-0.99)	(1.91)	(2.25)
BD	0.320***	0.268***	0.139***	0.341***
	(12.11)	(9.14)	(4.66)	(12.06)
CO2	-1.72	0.000***	1.571***	-2.43***
	(-1.21)	(9.93)	(3.63)	(-1.88)
IND	0	0	0.160***	0.114***
	-	-	(8.97)	(7.87)
BS	0.284***	0.461***	0	0
	(2.94)	(4.08)	-	-
ROA	-65.62***	-61.34***	-59.97***	-116.0***
	(8.71)	(-7.34)	(-9.37)	(-8.57)
Constant	48.92***	52.39***	46.83***	50.23***
	(33.01)	(29.70)	(36.66)	(49.09)
Observations	1923	1923	1757	1757
R-squared	0.12	0.18	0.13	0.19

Notes: t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

V. CONCLUSION AND RECOMMENDATION

This study examined the impacts of digital financial inclusion on corporate ESG disclosure among financial and Islamic institutions. The empirical results suggest that fintech inclusion positively affects banks' ESG disclosure due to a better information environment that encourages transparency and reduces information asymmetry. These positive implementations of digital technology support the sustainable behavior of banks and institutions while receiving positive signals from the market. This direct relationship which aligns with signaling and agency theories (Khan, 2022), improving strategic oriented performance (Ding et al., 2022; Lee & Wang, 2022).

The findings of this study offer critical policy implications for investors and stakeholders by emphasizing the role of digital financial inclusion (DFI) in enhancing ESG disclosure, reducing information asymmetry, and fostering financial transparency. Investors can leverage improved ESG reporting to make informed decisions, particularly in Islamic banking, where ethical considerations are vital in investment choices. For stakeholders, including regulators and policymakers, promoting DFI policies can strengthen corporate governance by ensuring greater accountability and reducing agency conflicts. The study also highlights the potential for ESG-linked investment products, such as green bonds and sustainable Sukuk, to align financial growth with responsible investing. Additionally, by integrating digital financial tools, financial institutions can mitigate systemic risks, enhance market stability, and support sustainable development goals (SDGs) by increasing financial accessibility and promoting green finance. These insights

provide investors, policymakers, and financial institutions a strategic roadmap to harness DFI for advancing ESG transparency, financial stability, and sustainable economic growth.

Policymakers can enhance digital financial inclusion by encouraging banks to adopt digital financial technologies. This can be accomplished by facilitating access to resources and promoting transparent and accessible financial information for financial institutions. Financial literacy instructions can improve businesses' awareness and utilization of digital finance tools, leading to more effective and responsible execution. Regulatory organizations might collaborate with financial institutions to develop risk management frameworks. These frameworks can efficiently mitigate and reduce any potential negative external impacts due to implementing digital banking.

Financial institutions should benefit from the potential consequences associated with the advancement of digital finance and implement a system for disclosing ESG information. Individuals must understand the significance of investment and prioritize the harmonious progress of environmental and social governance.

Regulators can create a practical and required ESG mandatory information system and embed ESG performance into the regulatory framework. It should direct industries to participate in responsible investment and finance institutions to advance sustainable development. Authorities and financial institutions should prioritize establishing digital infrastructure and expanding digital finance in economically underdeveloped regions. DFI has a capacity to access financial services for regulators to promote social inclusion and economical empowerment through digital forums which are more transparent and efficient. Banks digital credits and savings can assist organizations to enhance governance practices and implement eco-friendly technologies. This leads secure and inclusive digital eco systems which can be strategically accelerate progress towards ESG goals. However, policymakers and investors must prioritize technological infrastructure, data driven privacy practices and ESG reporting standards in the financial institutions which can amplify positive externalities of digital financial inclusion for banks.

The government should capitalize on the synergistic and mutually beneficial impacts of inclusive finance and green financing. Investors should thoroughly evaluate banks' ESG performance before making investment decisions. Extreme climate disasters can have detrimental impacts on institutions. However, these institutions can mitigate their investment risks by focusing on banks' environmental performance. Sustainability offers everlasting financial benefits for investors.

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APPENDIX

Table A1.
Sample Distribution by Countries

Country of Exchange	Freq.	Percent	Cum.
Argentina	78	0.89	0.89
Australia	468	5.35	6.24
Austria	65	0.74	6.98
Belgium	65	0.74	7.73
Brazil	143	1.63	9.36
Canada	312	3.57	12.93
Chile	78	0.89	13.82
Czech Republic	26	0.30	14.12
Denmark	91	1.04	15.16
Finland	26	0.30	15.45
France	91	1.04	16.50
Germany	91	1.04	17.54
Greece	78	0.89	18.43
Hong Kong	442	5.05	23.48
India	234	2.67	26.15
Indonesia	39	0.45	26.60
Ireland; Republic of	26	0.30	26.90
Italy	234	2.67	29.57
Japan	507	5.80	35.37
Korea; Republic (S. Korea)	260	2.97	38.34
Malaysia	116	1.33	39.67
Mexico	52	0.59	40.26
Netherlands	26	0.30	40.56
New Zealand	65	0.74	41.30
Norway	39	0.45	41.75
Philippines	52	0.59	42.34
Poland	117	1.34	43.68
Portugal	13	0.15	43.83
Russia	65	0.74	44.57
Singapore	52	0.59	45.16
South Africa	208	2.38	47.54
Spain	91	1.04	48.58
Sweden	195	2.23	50.81
Switzerland	169	1.93	52.74
Taiwan	195	2.23	54.97
Thailand	78	0.89	55.86
Turkey	91	1.04	56.90
United Kingdom	442	5.05	61.96
United States of America	3328	38.04	100.00
Total	8748	100.00	

Table A2.
Sample Distribution By Sectors with All Observations

Sectors	Freq.	Percent	Cum.
Banks	4289	49.03	49.03
Consumer Lending	468	5.35	54.38
Corporate Financial Services	221	2.53	56.90
Diversified Investment Services	78	0.89	57.80
Financial & Commodity Market Operators & Service Providers	234	2.67	60.47
Investment Banking & Brokerage Services	520	5.94	66.42
Investment Holding Companies	221	2.53	68.94
Investment Management & Fund Operators	845	9.66	78.60
Life & Health Insurance	624	7.13	85.73
Multiline Insurance & Brokers	325	3.72	89.45
Property & Casualty Insurance	806	9.21	98.66
Reinsurance	117	1.34	100.00
Total	8748	100.00	

Table A3.
Sample distribution by Sector

Sectors	Freq.	Percent	Cum.
Banks	324	49.09	49.09
Consumer Lending	36	5.45	54.55
Corporate Financial Services	17	2.58	57.12
Diversified Investment Services	6	0.91	58.03
Financial & Commodity Market Operators & Service Providers	18	2.73	60.76
Investment Banking & Brokerage Services	37	5.61	66.36
Investment Holding Companies	14	2.12	68.48
Investment Management & Fund Operators	65	9.85	78.33
Life & Health Insurance	47	7.12	85.45
Multiline Insurance & Brokers	25	3.79	89.24
Property & Casualty Insurance	62	9.39	98.64
Reinsurance	9	1.36	100.00
Total	660	100.00	