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# The Effect of Digital Washing on Firm Value: The Mediating Role of ESG Performance

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**Abstract**

Digital transformation has become a strategic pillar for firms; however, it requires substantial time, resources, and investment. These challenges have led to the emergence of an alternative phenomenon, digital washing. Using 2527 samples spanning six years, this study investigates the effect of digital washing on firm value and examines whether ESG performance mediates this relationship in the context of ASEAN-4, which includes Malaysia, Indonesia, the Philippines, and Thailand, together with Vietnam. Path analysis and bootstrapping were conducted. The research results indicate that digital washing positively affects firm value, yet ESG performance does not play a statistically significant mediating role. These findings enrich the literature by clarifying the effects of digital washing; moreover, they provide updated empirical evidence from the ASEAN-4 and Vietnam, where research on digital washing remains scarce.

**Keywords:** digital washing; ESG performance; firm value

## 1. Introduction

Digital transformation (DT) has become a structural priority for firms and economies worldwide, driven by rapid technological advancements and stronger competitive pressure (Plekhanov et al. 2023). As global competitiveness increasingly depends on digital readiness, countries—especially developing economies—face huge pressure to shift toward digitally enabled growth (OCDE 2020; World Bank 2023).

Within Southeast Asia, DT has spread rapidly but unevenly. The Association of Southeast Asian Nations (ASEAN) has formally recognized digitalization as a strategic pillar for sustainable growth, emphasizing investments in digital infrastructure, data governance, skills development, and digital financial inclusion (ASEAN Secretariat 2021). These variations create an important context for comparative research on DT in key ASEAN economies.

This study focuses on the ASEAN-4 (Indonesia, Malaysia, Thailand, and the Philippines) and Vietnam. Although ASEAN-5 often includes Singapore, it is excluded from this analysis as it is a developed country and the main recipient of financial flows, accounting for about 38% of the total FDI among the five countries (Baek et al. 2023). Vietnam is included as it has emerged as a dynamic digitalizing economy, playing a crucial role in regional supply chains and technological innovation (Zhang et al. 2025; Hien and Tam 2025). The Vietnamese Government launched the National DT Program to 2025, with Orientation to 2030, under Decision 749/QĐ-TTg in 2020, with the goals of developing

Check for updates

Academic Editor: Syed Shams

Received: 4 June 2026
Revised: 27 July 2026
Accepted: 30 July 2026
Published: 19 August 2026

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a digital government, economy, and society (Government of Vietnam 2020). In line with governmental decrees, by the end of 2024, DT contributed 13.17% of the national GDP (Do 2025).

Additionally, across the ASEAN-4 and Vietnam, DT has accelerated in recent years. Specifically, Indonesia has emerged as ASEAN's largest digital economy, supported by government incentives, digital infrastructure investment, and public–private collaboration (Abdurrahman 2025). Malaysia has advanced DT through national initiatives that have strengthened digital connectivity, although challenges related to rural inclusion and long-term digital capability remain (Chong et al. 2025). Additionally, Thailand has enhanced digitalization in public services, improving administrative efficiency and transparency while continuing to address data integration and interoperability issues (Čaplánová and Szakadátová 2025; Tissayakorn 2025). Meanwhile, the Philippines has experienced rapid digital adoption among micro, small, and medium enterprises, although the diffusion of advanced technologies remains constrained by financial, infrastructural, and skill-related barriers (Cordova et al. 2025). Similarly, Vietnam has demonstrated strong DT momentum, with digitalization contributing to productivity growth, foreign direct investment, and governance efficiency (Vu et al. 2025). Collectively, these developments underscore the region's rapid DT while highlighting persistent disparities in digital readiness and implementation across countries.

A review of previous research on the subject of DT's impact on firm value (FV) reveals that the relationship differs depending on the time period and firm's background. Most studies show an overall positive and beneficial effect for companies adopting such initiatives. Based on a panel of 2254 Chinese manufacturing firms from 2010 to 2020 (Guo and Xu 2021), the intensity of DT was found to be positively correlated with operational performance. (Leão and da Silva 2021) revealed that DT generally enhances firms' competitiveness. However, there has also been a study that found a negative relationship between DT and FV (Jardak and Ben Hamad 2022). In parallel, DT has been linked to improved environmental, social, and governance (ESG) performance (Jin and Wu 2024), while ESG performance has also been shown to increase FV (Xie et al. 2019).

However, authentic DT requires substantial financial, technological, and organizational resources, which remain limited for many firms operating in developing economies. Under these constraints, some firms may resort to DW—the symbolic exaggeration of DT efforts through corporate disclosures—to satisfy stakeholder expectations without undertaking substantive organizational change. Similar to greenwashing, DW creates an inflated impression of digital maturity while masking the gap between digital rhetoric and actual implementation. Although emerging evidence suggests that such symbolic disclosures may temporarily enhance market perceptions, they also undermine corporate credibility and increase exposure to adverse market outcomes, including stock price crash risk (Dinh et al. 2025). Nevertheless, the existing literature has predominantly focused on authentic DT in developed economies, leaving limited understanding of how symbolic digital disclosure affects firm outcomes in emerging institutional settings. In particular, the impact of DW on FV and the mechanisms through which this relationship operates, especially via ESG performance, remain unexplored.

To address these gaps, this study investigates both the direct and indirect effects of DW on FV in the ASEAN-4 countries and Vietnam, with particular emphasis on the mediating role of ESG performance. This research makes three main contributions to the literature. First, it extends the corporate disclosure and DT literature by providing empirical evidence on the valuation consequences of symbolic digital disclosure, thereby shifting attention from authentic DT to DW in emerging markets. Second, it advances understanding of the underlying mechanisms by examining whether ESG performance, both as an aggregate

construct and through its environmental, social, and governance dimensions, mediates the relationship between DW and FV. Third, it contributes methodologically by integrating machine learning-assisted text mining with panel data econometric techniques to develop a systematic measure of DW based on corporate annual reports. The empirical analysis employs regression with fixed-effects estimations and Driscoll–Kraay standard errors to evaluate the proposed relationships. By examining firms across diverse industries in emerging economies, this study provides new evidence on how symbolic digital disclosure translates into tangible economic outcomes and offers practical implications for managers, investors, and policymakers in evaluating the credibility of corporate DT initiatives and promoting sustainable digital development. In addition, the comparative evidence from the ASEAN-4 countries and Vietnam provides policy insights for strengthening sustainable digital transformation strategies in Vietnam.

The remainder of this paper is organized as follows: Section 2 provides the theoretical background. Section 3 reviews the existing literature and develops the hypotheses. Section 4 details the research methodology, data collection, and variable measurements. Section 5 presents the empirical results and discussion. Finally, Section 6 concludes the study, offering main findings, theoretical and methodological contributions, practical and policy implications, and directions for future research.

## 2. Theoretical Background

To fully explain the complex phenomenon of DW and its effect on ESG performance and FV, this study uses the following background theories: the theory of planned behavior (TPB), resource-based view theory (RBV), signaling theory, and stakeholder theory. Rather than treating these four core perspectives as parallel backgrounds, this research aligns them sequentially to map how symbolic actions are driven and evaluated.

TPB serves as our principal foundation for explaining the behavioral intentions behind corporate disclosure. Although originally developed to model individual intention based on attitude variables, subjective norm variables, and perceived behavioral control variables, which together indirectly impact behavior through intention (Ajzen 1980), its application is highly appropriate and has been increasingly adopted for firm-level strategic behaviors, particularly in voluntary reporting and impression management. Firms have a favorable attitude toward disclosing DT because it has a positive impact on FV (Yoo et al. 2024). These decisions are orchestrated by senior executives or corporate boards, whose collective managerial intentions act as organizational proxies. Moreover, due to social pressure—a subjective norm—they expect enterprises to undergo DT, and they evaluate firms from an external perspective (Ta and Lin 2023). However, firms struggle with DT because of limitations in human resources, including a lack of a business-oriented digital workforce (Uzule and Verina 2023; Seppänen et al. 2025), insufficient financial resources, and technological requirements (Restrepo-Morales et al. 2024). When subjective pressures are high but internal behavioral control is low, managerial intention steers toward a cost-effective alternative: digital washing, which achieves the appearance of conformity without the associated asset deployment.

The remaining three theories focus on resources, signals, and stakeholders, defining the analytical mechanisms through which this TPB-driven intention manifests and affects FV. While TPB illustrates why a firm decides to engage in digital washing, RBV, signaling theory, and stakeholder theory explain how the market processes this symbolic behavior.

RBV suggests that the value and development of firms should be their heterogeneous resources (Penrose 2009), which give firms a competitive advantage. Through DT, firms are able to create rare and inimitable digital capabilities, thereby increasing FV. ESG per-

formance is considered to be an intangible resource of firms (Daft 2015), and firms have competitive advantages by applying alternative ESG strategies.

Signaling theory provides a framework for understanding how parties in an information asymmetric environment convey credible information to reduce uncertainty (Spence 1978). Firms increasingly utilize technologies to improve operational efficiency and signal transparency, innovation, and governance quality to the market (Verhoef et al. 2021). Adopting digital technologies is costly, requires long-term commitment, and is easily observable by external stakeholders—characteristics that make it a strong signal according to the conditions outlined by Connelly et al. (2011). Thus, DT can serve as a strategic signal that a firm possesses advanced capabilities in data management and information disclosure, which reassures investors of the firm's integrity and reduces perceived information risk.

Stakeholder theory suggests that firms achieve long-term sustainability by aligning the interests of all stakeholders (Freeman 2010). As a strategic framework, ESG indicators are increasingly used to evaluate firms' overall performance across four key dimensions: financial performance, market and risk perception, strategic positioning, and capital structure. This underscores the importance of standardized multi-dimensional assessments to reflect diverse stakeholder interests and enable meaningful comparisons across firms, rather than relying on a single-dimensional evaluation (Da Cunha et al. 2025).

Collectively, these four theories support our research model through a cohesive framework: TPB explains the initiation of DW under strategic resource constraints, RBV establishes the ideal resource baseline being projected, signaling theory governs the transmission of these symbolic claims to the market, and stakeholder theory dictates the external evaluation that ultimately determines FV.

## 3. Literature Review

### *3.1. Conceptual Boundaries of Digital Transformation*

DT is a process of fundamental organizational change enabled by the strategic deployment of digital technologies. Rather than merely adopting technological tools, this genuine process involves deep modifications to firms' structures, processes, and value creation mechanisms, effectively reshaping business models and strategic decision-making across the entire organization (Vial 2019). Because this process entails authentic, resource-intensive change, undertaking it acts as a substantive signaling behavior that credibly communicates a firm's true operational capabilities to the market.

In contrast, some firms seek to project this positive market signal without undergoing actual organizational change, relying instead on impression management through symbolic disclosure. This leads to the practice of DW, which is explicitly described as the symbolic side of digital transformation. Unlike DT, DW is a communication practice in which firms disclose misleading information and overstate their digital transformation efforts relative to their true capabilities (Dinh et al. 2025). It is fundamentally defined as "the act of exaggerating and fabricating a firm's level of digital transformation, indicated in the gap between its goal-oriented promises and limited actual performance" (Zor 2024). By utilizing this symbolic disclosure, firms aim to artificially improve financial efficiency, internal operations, and sustainable development through superficial technical changes and misleading claims rather than implementing actual new information technology.

### *3.2. Digital Washing and Firm Value*

According to the current literature, while extensive research has examined the impact of authentic DT on FV, studies focusing on the valuation effects of DW are still emerging.

On the one hand, in the short term, DT has a negative impact on FV when it is measured by Return on Assets. This is explained by (Jardak and Ben Hamad 2022), who

argued that investments in digital maturity may take many years to be reflected in a firm's financial indicators. Moreover, because information technology assets are either not depreciated or their depreciation is shown slowly, they negatively affect a firm's financial indicators in the short term.

On the other hand, also in Jardak and Ben Hamad (2022), in the long-term, by utilizing DT, companies can maximize FV. DT is not only about fostering technological innovation (Liu et al. 2023) but also about changing internal structures, enhancing collaboration across various functions, and boosting efficiency in production and organizational processes (Zhao et al. 2023). Moreover, DT redefines how companies deliver value to customers (Kraus et al. 2022), thereby promoting the value of their products and services to external stakeholders and, as a result, increasing FV (Vial 2019). Although DT requires a long period of time, it is a core element driving future competitiveness for firms (Ancillai et al. 2023), creating sustainable competitive advantages and thereby forming long-term value for customers while enhancing overall FV (Verhoef et al. 2021).

However, many firms face challenges in DT due to financial constraints and technological gaps (Uzule and Verina 2023; Seppänen et al. 2025; Restrepo-Morales et al. 2024); as a result, some turn to DW. To better understand how firms may exaggerate their digital progress, we break DW into three dimensions that mirror the main layers of DT. First, digital technology adoption washing involves overstating the use of visible tools such as cloud systems, IoT devices, AI applications, or advanced computing (Kindermann et al. 2021; Zhai et al. 2022). Second, business model innovation washing entails exaggerating strategic, customer-facing changes, including platform-based services, digital payments, and data-driven offerings (Verhoef et al. 2021; Wu et al. 2021). Third, digital strategy implementation washing refers to fabricating broader plans and structures, such as digital roadmaps, enterprise resource planning, and application programming interface integration (Sebastian et al. 2020; Kindermann et al. 2021). Because prior research (Zhai et al. 2022) shows that higher levels of genuine DT improve firm performance, investors react positively when they perceive these signals as drivers of operational and financial gains. As a result, firms can boost FV through these symbolic claims even when actual DT remains limited. Therefore, together with TPB:

**H1.** *Digital washing has a positive effect on firm value.*

However, while the signaling of digital readiness brings short-term benefits, it is imperative to address the long-term theoretical implications of this symbolic behavior. Drawing parallels to greenwashing, DW is essentially used to artificially build a "digital reputation" without substantive backing. As highlighted by (Rosamartina et al. 2022), digital reputation is a critical intangible asset that significantly influences firm performance. By engaging in DW, firms inherently generate digital reputation risk. In the long run, if the discrepancy between the firm's inflated digital claims and its actual limited capabilities is discovered by the market, this artificial reputation deteriorates. Consequently, the realization of this digital reputation risk can severely damage stakeholder trust and degrade long-term company performance, even if the initial short-term market reaction was positive.

### *3.3. Digital Washing and ESG Performance*

Some studies have found a complex relationship between DT and ESG performance, suggesting that it is U-shaped (Wang et al. 2023). In addition, applying DT in its early stages involves challenges related to financial and operational resources and crowds out short-term ESG investments (Saeed et al. 2023), which could affect long-term sustainability goals (Jin and Wu 2024).

However, most previous research indicates a positive relationship between DT and ESG performance. DT is a key factor in enhancing ESG performance by applying digital technologies to bring major improvements, with the goals of lowering operating costs and increasing social responsibility, helping firms meet stakeholder expectations and enhance their overall enterprise value (Jin and Wu 2024). It enhances ESG performance by promoting transparency (Zhong et al. 2023), innovation (Jin and Wu 2024), and efficiency in corporate processes (Wang et al. 2023).

From an environmental perspective, in the research of Chen et al. (2020), DT has a negative effect on the environment because of increased consumption of resources and energy, as well as waste and emissions from production. However, DT improves business development sustainability (Feroz et al. 2021) by enabling new business models that fundamentally focus on the environment (Goralski and Tan 2020) and by improving the efficiency of information use through the adoption of technologies across the product life cycle (Chen et al. 2020)

Regarding the social pillar, some studies argue that the development of DT can challenge security, privacy, misinformation, and social division (Paul et al. 2024). On the other hand, DT improves operational competencies and customer experience (Nasution et al. 2025). It also enhances the way people connect and access information (Cetulean et al. 2023).

In terms of governance, DT influences firm governance by increasing information transparency and reducing information asymmetry (Li et al. 2024), which raises the efficiency of monitoring the production process and results in improved enterprise operations (Wang et al. 2023). Moreover, DT enhances the sharing of resources with external enterprises, helps meet the needs of multi-stakeholders and affects stakeholder governance (Sun and Guo 2024). Additionally, DT increases accounting reliability, which improves the overall level of firm governance and results in reinforced sustainable practices (Fang et al. 2023).

Based on TPB, DW and DT send the same signal to external stakeholders. This research proposes the following hypothesis:

**H2.** *Digital washing has a positive influence on ESG performance.*

### *3.4. ESG and Firm Value*

When approaching FV, there is considerable debates about the effect of ESG on it. By using meta-analysis of more than 2000 prior research papers, Friede et al. (2015) found that 48% of the papers written between 1970 and 2015 indicated a positive relationship between ESG and firm performance, while 11% reported a negative relationship and 23% reported a neutral relationship.

However, most studies indicate a positive correlation between ESG performance and FV (Xie et al. 2019). Many external stakeholders claim ESG as a signal for evaluating business sustainability (Limkriangkrai et al. 2017) because it enhances operational efficiency (Brammer and Millington 2005), improves corporate reputation (Menon and Kahn 2003), increases employee productivity and capital market benefits (Dhaliwal et al. 2011), and prevents risk problems. Therefore, they can be considered as an advantage for competitiveness and sustainable management strategies (Deng and Cheng 2019; Xie et al. 2019).

Specifically, each component of ESG performance also impacts FV. Research indicates that corporate performance regarding environmental responsibility can significantly boost corporate financial performance by reducing operating costs and capital costs while increasing revenue (Curcio and Wolf 1996). Bad environmental performance is negatively correlated with a firm's intangible asset value (Konar and Cohen 2001). Environmental performance demonstrates a company's concern for environmental and social issues, which

is expressed through Corporate Social Responsibility and is positively received by society, raising FV (Wahidahwati and Ardini 2021).

Societal factors are often studied under the heading of Corporate Social Responsibility (CSR). CSR participation has been shown to increase FV (Jo and Harjoto 2011). In particular, CSR activities that concentrate on internal social enhancement and product quality tend to enhance FV effectively (Jo and Harjoto 2011). Social capital, including civic cooperation and interpersonal trust, emerges as an important determinant of FV (Fernández and González 2017).

Strong corporate governance is often associated with improved financial performance and greater investor attraction (Wang 2023). Numerous studies have found that firm-level corporate governance and firm valuation are strongly and favorably correlated (Ammann et al. 2011). Effective corporate governance can positively impact FV, with better-governed firms having lower capital cost (Zaharia and Zaharia 2012). Internal governance factors, such as board leadership and independence, institutional ownership, and analyst following, are related to FV (Brown and Caylor 2006). Combined with TPB, the following hypothesis is proposed:

**H3.** *ESG performance has a positive influence on firm value.*

### *3.5. The Mediating Role of ESG Performance*

Prior research indicates the mediating role of ESG, Yang (2025) showed that ESG performance mediates the influence of DT on the high-quality development of enterprises, while Luan and Wang (2023) pointed out the mediating role of ESG performance in the relationship between open innovation and enterprise value, indicating that firms pursuing open innovation can strengthen value creation through improved ESG performance. In particular, Wang and Xia (2024) studied the mediation of ESG performance in the relationship between DT and FV, implying that digital transformation can indirectly influence FV by enhancing ESG performance.

Combined with Sections 3.2 and 3.3, it is believed that ESG and each of its component play an indirect role in the influence of DT on FV. Together with TPB, ESG is assumed to mediate the influence of DW on FV. Therefore, this research proposes the following hypothesis:

**H4.** *ESG mediates the impact of digital washing on firm value.*

## 4. Methodology

### *4.1. Data and Sample*

The sample comprises listed firms from the ASEAN-4 countries and Vietnam. The initial sample size is 3695 over six years. To ensure data integrity and consistency, all observations with missing values for any variables are excluded (Little and Rubin 2019), and continuous variables are winsorized at the 1 and 99% quantiles. After the process, the dataset comprises 528 firms (2527 samples in total) spanning six years.

The data for the mediating, dependent, and control variables are collected from the Bloomberg database. For the independent variables—DW and its dimensions—this research adopts the method of text mining and machine learning for measurement, according to the methods used in similar research on DW and earnings management in corporate finance (Zor 2024).

### *4.2. Variables*

#### 4.2.1. Dependent Variable

Firms' value refers to a firm's ability to generate sustainable performance internally and the extent to which external stakeholders recognize this performance. This study uses Tobin's Q as a measure of firm value.

#### 4.2.2. Independent Variable

To reflect the subtle and complex nature of digital washing (DW), this research developed a multi-stage method to measure it. As DW is not directly observable, and there is no international measurement of actual digital transformation as a benchmark, the measurement of it must include multiple steps to measure the degree of promises, actions, and expected actions to reach the final calculation of DW levels. The measurement method includes three stages, which are adopted from Wei et al. (2025) with several developments in stage 2.

*Stage 1: Text mining and the quantification of promises and actions at year* $t-1$

DW is the act of exaggerating or fabricating a firm's level of digital transformation (DT), as indicated by the gap between its goal-oriented promises and its limited actual performance (Zor 2024). Therefore, to indicate the degree of DW and its dimensions, the promises and actual actions must be measured separately, denoted by DTA and DTW (DT actions and DT words), respectively.

Text mining is an available method and has been proven to be effective through its utilization in much research on DT in divergent contexts (Zhao et al. 2023; Celestin and Mishra 2025; Wei et al. 2025). Text mining using Python 3.13.5, in this research, is used to analyze the annual reports of firms to measure their promises and actual actions in terms of DT. Before the annual reports are analyzed, the texts are standardized by tokenization, removing punctuation and lowercasing.

As the annual reports comprise both statements on the past year's actual actions and promises for the following year, the report is identified into the parts of "actual actions", "promises", and "others" (which is neither actions nor promises). This separation is through text segmentation with the heading-based rule. This approach is based on the legal constructs of annual reports, requiring a strict separation of report sections on operating and business performance and future strategies (such as "plan" and "outlook") according to information disclosure regulations in most markets. By applying word-boundary regular expressions, the algorithm ensures objectivity and was proven effective in text mining in precedent research (Li et al. 2025). After segmentation, keyword frequency analysis is applied to measure the occurrence of relevant terms in each section.

A dictionary of digital transformation-related keywords with three dimensions is constructed to serve textual analysis in academic and practical approaches (Table 1). From an academic approach, digital technologies bring about disruptions, which require firms' strategies and adaptation, thereby leading to business model changes and value redefinition for firms (Verhoef et al. 2021). From a practical perspective, DT is about four key aspects: AI, big data, cloud computing, and blockchain (Wu et al. 2021). The dictionary is used to count the frequency of keyword occurrences in each category. The dictionary is adopted mainly from Fedorova et al. (2025), with further development by the authors through consultation with an expert in corporate finance. The results are then divided by the total number of words counted in the whole annual report to standardize them; thereby, DTA and DTW for a particular year are measured.

**Table 1.** Dictionary extract.

| Category | Keywords | Source |
| --- | --- | --- |
| Digital technology adoption washing | Advanced communications, advanced technology, advanced technologies, app, apps, bandwidth, blockchain, bot, broadband, cloud, and cloudbased | Kindermann et al. (2021) |
| | Cloud computing, streaming computing, graph computing, in-memory computing, secure multi-party computation, and brain-like computation | Wu et al. (2021) |
| | Digital technology uses digital tools, such as 5G mobile networks and 3D printing | Zhai et al. (2022) |
| Business model innovation washing | Analytics, artificial intelligence, autonomous, big data, Bluetooth, compute, computing, and connectivity | Kindermann et al. (2021) |
| | Machine learning, deep learning, E-commerce, Mobile Payment, Third Party Payment, NEC Payment, B2B, C2B, B2C, C2C, O2O, Internet Finance, and Digital Finance | Wu et al. (2021) |
| | Social, mobile, digital platforms, and operation efficiency | Verhoef et al. (2021) |
| Digital strategy implementation washing | Digital strategy, customer loyalty and trust, superior, innovative, and personalized and integrated customer experiences | Sebastian et al. (2020) |
| | Mobile internet, industrial internet, internet healthcare, netlink, smart energy, and smart grid | Wu et al. (2021) |
| | Application programming interface, API, APIs, desktop, desktops, device, devices, ecommerce, e-commerce, and enterprise resource planning | Kindermann et al. (2021) |

(source: authors' synthesis).

*Stage 2: ML regression and prediction of expected actual actions at time t*

To establish a market baseline for the expected DTA in year t + 1, a simple machine learning linear regression approach with scikit-learn library in Python is employed to process each individual-year dataset separately (including six datasets ranging from 2018 to 2023 for the prediction of 2019–2024). This separation of the datasets is executed to ensure that the machine learns the market rule of "promise and action" in each year. A one-lag selection is chosen according to the standard corporate fiscal cycle (one year). The expected level of digital transformation at time t (denoted by DTAf) is predicted based on the level of digital transformation commitment (DTW) at time $t - 1$. The sample of this research ensures a sufficiently large sample size for splitting the data into training and testing sets (80:20), guaranteeing that the matrix is non-singular and helping to avoid over-fitting.

The results of prediction models are presented in Appendix A (Table A1). Overall, during the period of the predicted years, the simple ML regression has a positive coefficient across all expected digital actions, meaning the general market rule proposes an increase in actions when a commitment is made. The prediction models also exhibit consistent accuracy due to the MSE and RMSE being near 0, positively high R-square values, and statistical significance ($p$-value < 0.05) across most years, except for years with common market shocks (INAf in 2020). The coefficients serve as the market's expectation of firms' actions after learning from the given sample; therefore, the residual calculations in the following stage provide a final measurement of DW actions.

The ML regression in this stage is a development in terms of method compared to the adopted one, which employed OLS regression with the average level of DT in firms within the same industry as an independent variable. The applied method is capable of providing

a commitment-driven baseline, bias-free estimation (sample split for testing and training), and dynamic annual adjustment.

*Stage 3:*

The forecasted value of DTA at time t (DTAf_t) is then subtracted from the actual DTA at time t (DTA_t); thereby, the degree of DW at time t is measured. The same method is used for the component constructs of DW.

The detailed workflow is presented in the Supplementary Materials.

#### 4.2.3. Mediating Variable

The ESG performance of firms is measured by the ESG score retrieved from the Bloomberg database (Table 2).

**Table 2.** Variable measures.

| Variable Name | Variable Symbol | Variable Measurement | Source |
|---|---|---|---|
| Digital washing | DW | $DW_t = DTAf_t - DTA_t = DTAf_t - (AA_t + INA_t + IMA_t)$ | Adopted method of Wei et al. (2025) |
| Digital technology adoption washing | AW | $AW_t = AAf_t - AA_t$ (AA: Digital technologies adoption action) | |
| Business model innovation washing | INW | $INW_t = INAf_t - INA_t$ (INA: Business model innovation action) | |
| Digital strategy implementation washing | IMW | $IMW_t = IMAf_t - IMA_t$ (IMA: Digital strategy implementation action) | |
| Firm value | FV | Calculated by Tobin's Q | Bloomberg |
| ESG performance | ESG | Bloomberg ESG composite score | Bloomberg |
| Environmental | E | Environmental score | Bloomberg |
| Social | S | Social score | Bloomberg |
| Governance | G | Governance score | Bloomberg |
| Book-to-market ratio | BM | Book value of equity/market value of equity | Bloomberg |
| Leverage | LEV | Total liabilities at year-end/total assets at year-end | Bloomberg |
| Return on assets | ROA | Net profit/average balance of total assets | Bloomberg |
| Size | SIZE | Natural logarithm of total corporate assets | Bloomberg |

### *4.3. Model*

As the digital washing and ESG performance variables have their sub-dimensional pillars, the research split the models into two main levels, including the aggregate level (using the composite values) and the sub-dimensional level (using the dimensional pillars).

To test whether DW has a positive effect on FV (H1), this research initially proposes the OLS model for regression analysis. The equations are as follows:

$$FV_{it} = \beta_0 + \beta_1 DW_{it} + \beta_2 BM_{it} + \beta_3 LEV_{it} + \beta_4 ROA_{it} + \beta_5 SIZE_{it} + YEAR_{fe} + \varepsilon_{it} \quad (1)$$

$$FV_{it} = \beta_0 + \beta_1 AW_{it} + \beta_2 INW_{it} + \beta_3 IMW_{it} + \beta_4 BM_{it} + \beta_5 LEV_{it} + \beta_6 ROA_{it} + \beta_7 SIZE_{it} + YEAR_{fe} + \varepsilon_{it} \quad (2)$$

To test the direct effects of the independent variables on the mediating ones (H2), the models are as follows:

$$ESG_{it} = \beta_0 + \beta_1 DW_{it} + \beta_2 BM_{it} + \beta_3 LEV_{it} + \beta_4 ROA_{it} + \beta_5 SIZE_{it} + YEAR_{fe} + \varepsilon_{it} \quad (3)$$

$$E_{it} = \beta_0 + \beta_1 AW_{it} + \beta_2 INW_{it} + \beta_3 IMW_{it} + \beta_4 BM_{it} + \beta_5 LEV_{it} + \beta_6 ROA_{it} + \beta_7 SIZE_{it} + YEAR_{fe} + \varepsilon_{it} \quad (4)$$

$$S_{it} = \beta_0 + \beta_1 AW_{it} + \beta_2 INW_{it} + \beta_3 IMW_{it} + \beta_4 BM_{it} + \beta_5 LEV_{it} + \beta_6 ROA_{it} + \beta_7 SIZE_{it} + YEAR_{fe} + \varepsilon_{it} \quad (5)$$

$$G_{it} = \beta_0 + \beta_1 AW_{it} + \beta_2 INW_{it} + \beta_3 IMW_{it} + \beta_4 BM_{it} + \beta_5 LEV_{it} + \beta_6 ROA_{it} + \beta_7 SIZE_{it} + YEAR_{fe} + \varepsilon_{it} \quad (6)$$

After testing the two individual regressions, two integrated models (an overall model of the main constructs and a model of the component construct) are employed to retest the significance of DW's direct effects on FV in the presence of the mediating variables (H1) and the direct influence of ESG and its pillars on FV (H3).

$$FV_{it} = \beta_0 + \beta_1 DW_{it} + \beta_2 ESG_{it} + \beta_3 BM_{it} + \beta_4 LEV_{it} + \beta_5 ROA_{it} + \beta_6 SIZE_{it} + YEAR_{fe} + \varepsilon_{it} \quad (7)$$

$$FV_{it} = \beta_0 + \beta_1 AW_{it} + \beta_2 INW_{it} + \beta_3 IMW_{it} + \beta_4 E_{it} + \beta_5 S_{it} + \beta_6 G_{it} + BM_{it} + \beta_8 LEV_{it} + \beta_9 SIZE_{it} + YEAR_{fe} + \varepsilon_{it} \quad (8)$$

The composite variables (DW, ESG) and its sub-variables (AW, INW, IMW and E, S, G) are not incorporated in a single model due to the possibility of multicollinearity created by the potential correlation between them, which may undermine the reliability of the results (Gujarati 2012). _fe represents the fixed effect; ε denotes the random error terms; and _it represents the effect in firm i at time t.

### *4.4. Hypothesis Testing Method*

This research employs an approach of path analysis and bootstrapping to validate the hypotheses.

Before the proposed hypotheses are tested, the descriptive and correlation matrix are calculated to provide the overall characteristics of the sample as well as to detect potential correlation and collinearity among the variables.

Subsequently, the regression models with Ordinary Least Squares (OLS), random effects (RE), and fixed effects (FE) estimators are estimated sequentially with the two integrated models (7 and 8). The results of the Breusch–Pagan test used to choose between the OLS and RE models (Breusch and Pagan 1980) reveal the presence of random effects (Table A2). The Hausman test was conducted and determined that FE models are more appropriate for both integrated models (Table A2). Several model deficiencies were diagnosed, including heteroskedasticity using the Kezdi test (Kezdi 2004) and cross-sectional dependence using the Pesaran CD test (Pesaran 2021). However, there is no multicollinearity assessed through the Variance Inflation Factor (VIF), which is calculated from the regression model after a demeaning transformation (Wooldridge 2010), and no autocorrelation, as tested by the Wooldridge test (Wooldridge 2010).

As the two integrated models hold the deficiencies of heteroskedasticity and cross-sectional dependence, the study applies Driscoll–Kraay (Driscoll and Kraay 1998) standard error estimators for direct effect analysis. Despite its common use for datasets with large time periods and small numbers of cross-sectional units, it has been proven to be applicable to datasets with large numbers of cross-sectional units and small time periods, as there is no limitation on the scale of N in comparison with T (Driscoll and Kraay 1998). Furthermore, this method can completely address the mentioned deficiencies, unlike clustered standard error, which cannot solve the issues of cross-sectional dependence.

After direct effect validation, a 5000-time bootstrap procedure clustered at the firm level is performed to test the significance of the mediation effect (H4); thereby, the indirect effects are also calculated.

Both the aggregate-level and sub-dimensional level models are tested to observe the influence of digital washing on firm value, as well as the mediating effect of ESG on this influence.

## 5. Research Results

### *5.1. Descriptive Results*

Before the hypotheses are tested, the descriptive statistics of the data are calculated. The results are shown in Table 3.

Aggregate digital washing (DW) has a mean value of 0.372, when the sub-dimensional values (AW, INW, and IMW) revolves around zero (ranging from −0.0018 to −0.0039). This difference in scale is attributed to the expectation gap in DW, which is amplified by the relatively constant high regression coefficients (β) and larger RMSE values in its ML models. These values are relatively higher than those of the individual sub-dimensional models (Table A1), meaning that the digital washing actions at the aggregate level are subject to a higher compounding market expectation. In terms of ESG performance, firms

have their Governance scores highest, followed by Social and Environmental performance. The mean value of composite ESG (3.781) reveals a low level of sustainable development among the sample firms.

**Table 3.** Descriptive results.

| Variable | N | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| DW | 2527 | 0.3720945 | 0.5204591 | −0.031398 | 1.766378 |
| AW | 2527 | −0.0039895 | 0.0070621 | −0.0287323 | 0.0166015 |
| INW | 2527 | −0.0018278 | 0.003938 | −0.0784966 | 0.010447 |
| IMW | 2527 | −0.0025263 | 0.0046126 | −0.0359041 | 0.010729 |
| ESG | 2527 | 3.780693 | 1.204898 | 0.73 | 7.59 |
| E | 2527 | 3.012782 | 1.796902 | 0 | 8.823503 |
| S | 2527 | 4.319374 | 2.127112 | 0 | 10 |
| G | 2527 | 4.735592 | 0.9525162 | 1.942732 | 8.711576 |
| FV | 2527 | 1.790577 | 2.576372 | 0.2354973 | 59.74609 |
| BM | 2527 | 1.128884 | 1.230025 | 0.0190776 | 7.65165 |
| LEV | 2527 | 2.348954 | 1.383517 | 1.046875 | 9.220725 |
| ROA | 2527 | 5.318045 | 7.19889 | −14.66419 | 33.34871 |
| SIZE | 2527 | 20.91112 | 1.44376 | 17.21134 | 23.98743 |

### *5.2. Correlation Matrix*

To identify possible multicollinearity issues, the correlation coefficients of all variables are examined. The correlation matrix is shown in Table A3. Although there are high correlations between several pairs of independent variables, the calculated VIF showed no multicollinearity.

### *5.3. Direct Effect Analysis*

The paths of effect from the independent variables to the mediating ones, and subsequently from the mediating variables to the dependent ones in the integrated models, are tested according to Equations (1)–(8). The utilized estimator is the Driscoll–Kraay standard error. The results are indicated in Table 4.

The coefficients of DW ($\beta = 1.099532$), AW ($\beta = 86.69627$) and INW ($\beta = 15.73809$) are significantly positive, with $p$-values smaller than 0.05, meaning that the positive effects of DW, AW and INW on FV are statistically significant. Firms, therefore, can in practice greatly enhance their value by conducting these actions, confirming H1, H1a, and H1b. The aggregate DW effect is mainly driven by AW and INW, which indicates that exaggeration in structural commitment affects market valuation the most. However, the conduct of IMW does not practically influence firm value ($\beta = -37.20309$; $p$-value $> 0.05$).

The paths of effect from the independent variables to the mediating ones are tested according to Equations (3)–(6). The variables E and S are omitted due to low within-firm variation during the investigated period. The results show no significant effects, with the coefficients being nearly close to zero ($p$-value > 0.05), rejecting H2 and its sub-hypotheses.

Subsequently, in the integrated models, the effects of digital washing actions remain significant with unchanged coefficient; however, there are no statistically significant effects in the path from the mediating variables to the dependent ones. Therefore, H3 and its sub-hypotheses are rejected.

**Table 4.** Direct effect results.

| | FV (1) | FV (2) | ESG (3) | E (4) | S (5) | G (6) | FV (7) | FV (8) |
|---|---|---|---|---|---|---|---|---|
| DW | 1.099532 ***<br>(7.26) | | 0.0000000000019<br>(1.14) | | | | 1.099532 ***<br>(7.26) | |
| AW | | 86.69627 **<br>(2.58) | | −0.000000000045<br>(−0.49) | 0.0000000000255<br>(0.49) | 0.000000000109<br>(0.83) | | 86.69627 **<br>(2.58) |
| INW | | 15.73809 **<br>(2.59) | | −0.000000000229<br>(−1.16) | −0.000000000082<br>(−1.03) | 0.000000000298<br>(1.17) | | 15.73809 **<br>(2.59) |
| IMW | | −37.20309<br>(−0.91) | | 0.000000000147<br>(1.10) | −0.0000000000182<br>(−0.54) | −0.000000000246<br>(−1.18) | | −37.20309<br>(−0.91) |
| ESG | | | | | | | 1.724039<br>(1.05) | |
| E | | | | | | | | |
| S | | | | | | | | |
| G | | | | | | | | 1.533378<br>(1.19) |
| BM | −0.237235 **<br>(−2.97) | −0.2307152 **<br>(−3.05) | 0.00000000000158<br>(1.36) | −0.00000000000192<br>(−1.36) | −0.000000000000917<br>(−1.36) | 0.00000000000258<br>(1.37) | −0.237235 **<br>(−2.97) | −0.2307152 **<br>(−3.05) |
| LEV | 0.0323005<br>(1.39) | 0.031517<br>(1.29) | −0.0000000000002<br>(−0.73) | 0.00000000000017<br>(0.62) | 0.000000000000228<br>(1.17) | −0.000000000000084<br>(−0.24) | 0.0323005<br>(1.39) | 0.031517<br>(1.19) |
| ROA | 0.0331907 **<br>(4.96) | 0.0331693 **<br>(5.43) | −0.00000000000012<br>(−0.86) | 0.000000000000136<br>(0.77) | 0.0000000000000702<br>(0.77) | −0.000000000000187<br>(−0.82) | 0.0331907 **<br>(4.96) | 0.0331693 **<br>(1.29) |
| SIZE | −0.2348083<br>(−0.79) | −0.2415172<br>(−0.82) | 0.0000000000555<br>(1.44) | −0.0000000000716<br>(−1.44) | −0.0000000000368<br>(−1.44) | 0.0000000000914<br>(1.44) | −0.2348083<br>(−0.79) | −0.241517<br>(−0.82) |
| 2019 | | | | | | | | |
| 2020 | −0.8226198 ***<br>(−7.41) | −0.0306474<br>(−1.48) | −0.00000000000412<br>(−0.34) | 0.00000000000369<br>(1.11) | 0.00000000000128<br>(0.51) | −0.0000000000056<br>(−1.14) | −0.8226198 ***<br>(−7.41) | −0.0306474<br>(−1.48) |
| 2021 | 0.055937<br>(1.72) | −0.0027072<br>(−0.07) | −0.00000000000534<br>(−0.32) | 0.00000000000722<br>(1.23) | 0.00000000000273<br>(0.78) | −0.00000000000983<br>(−1.20) | 0.055937<br>(1.72) | −0.0027072<br>(−0.07) |

**Table 4.** *Cont.*

| | FV (1) | FV (2) | ESG (3) | E (4) | S (5) | G (6) | FV (7) | FV (8) |
|---|---|---|---|---|---|---|---|---|
| 2022 | −0.1702756 ** (−4.99) | −0.223381 *** (−7.57) | −0.00000000000614 (−0.30) | 0.00000000000816 (1.18) | 0.00000000000330 (0.79) | −0.0000000000110 (−1.15) | −0.1702756 ** (−4.99) | −0.223381 *** (−7.57) |
| 2023 | −0.1637215 ** (−2.80) | −0.2257255 ** (−5.05) | −0.00000000000813 (−0.39) | 0.0000000000105 (1.28) | 0.00000000000466 (0.95) | −0.0000000000142 (−1.26) | −0.1637215 ** (−2.80) | −0.2257255 ** (−5.05) |
| 2024 | −0.1894668 ** (−3.16) | −0.2674148 ** (−6.61) | −0.00000000000949 (−0.45) | 0.0000000000126 (1.33) | 0.00000000000591 (1.05) | −0.0000000000168 (−1.30) | −0.1894668 ** (−3.16) | −0.2674148 ** (−6.61) |
| Observations | 2527 | 2527 | 2527 | 2527 | 2527 | 2527 | 2527 | 2527 |
| R-square (within) | 0.0924 | 0.0989 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0924 | 0.0989 |
| F-statistics | (10, 5) 1247.74 | (12, 5) 190.04 | (10, 5) -- | (12, 5) -- | (12, 5) -- | (12, 5) -- | (10, 5) 1299.06 | (12, 5) 210.82 |

*** $p$-value < 0.001; **: $p$-value < 0.05.

### *5.4. Indirect Effect Analysis*

A bootstrap of 5000 times, clustered at the firm level, is conducted based on pooled OLS with year fixed effects due to the low within-firm variation of the ESG variables across the investigated years. The utilization of the Driscoll–Kraay standard error adjustment is not necessary, as the bootstrapping converges to a normal distribution. Both the aggregate and the sub-dimensional models reveal an insignificant mediating effect (Table 5), rejecting H4.

**Table 5.** Indirect effect results.

| Model | Path | Observed Coefficient | *p*-Value |
|---|---|---|---|
| Model 7 | DW => ESG => FV | −0.0002713 | 0.849 |
| | Total indirect effect | 5,360,000,000 | 0.031 |
| Model 8 | AW => E => FV | −0.1302019 | 0.591 |
| | AW => S => FV | 0.4066904 | 0.275 |
| | AW => G => FV | −0.0079233 | 0.984 |
| | INW => E => FV | −0.0623655 | 0.860 |
| | INW => S => FV | 0.3755963 | 0.531 |
| | INW => G => FV | −0.0125498 | 0.978 |
| | IMW => E => FV | 0.2134685 | 0.637 |
| | IMW => S => FV | −0.6232216 | 0.301 |
| | IMW => G => FV | 0.022205 | 0.976 |
| | Total indirect effect | 0.181698 | 0.644 |

Particularly in Model 7, the specific indirect path from DW to FV through composite ESG is non-significant ($\beta = -0.00027$, $p$-value = 0.849 > 0.05). Similarly, in Model 8, no specific indirect paths from the sub-dimensions (AW, INW, and IMW) to the final variable—FV via the individual ESG pillars (E, S, and G)—exert statistical significance ($p$-values range from 0.275 to 0.984), contributing to an insignificant overall indirect effect ($\beta = 0.1817$, $p$-value = 0.644). The results of the bootstrapping confirm that ESG factors do not act as a mediating mechanism in the impact of digital washing conduct on firm value.

### *5.5. Robustness Test*

This research tests the robustness of the results by using another proxy for the dependent variable—FV—by changing the calculation method to the natural logarithm of the firm's capitalization value (Saha 2024). The results are approximately consistent in terms of path effects and directions (Table A4). There is only the effect of INW, which exerts a slight discrepancy from the original model—an insignificant path. However, consistent results in most paths of both the direct and indirect effects show the robustness of the research findings.

## 6. Discussion

Our findings indicate that DW, when considered as a composite structure, has a positive and statistically significant effect on FV in both the ASEAN-4 and Vietnam.

Firstly, the results illustrate that digital technology adoption washing—the first level of DW—exerts the strongest positive influence on FV. This category shows fundamental and highly visible forms of DT, which can be readily observed and easily communicated (Kindermann et al. 2021; Zhai et al. 2022). A reasonable explanation is that technology adoption sends a clear and tangible signal to the market, suggesting better operational efficiency, greater scalability, and more modernized processes. Investors tend to view these improvements as significant signs of short-term performance gains. Consequently, even when firms exaggerate the extent of technology adoption, the market may still respond pos-

itively because investors have limited ability to verify the authenticity of such disclosures in the short run.

Secondly, business model innovation washing demonstrates a positive relationship with FV. These innovations are more complex, long-term and less immediately verifiable than digital technology adoption. These announcements often stimulate favorable expectations among investors and stakeholders, as business model innovation is associated with future market expansion and improved competitiveness among other companies.

In contrast, digital strategy implementation washing does not influence FV. Strategic statements are often broad, qualitative, and lack observable evidence of execution (Sebastian et al. 2020). Investors view these announcements as overly generic or symbolic, making them less credible signals of actual transformation. Thus, the market is unlikely to reward firms that merely claim digital strategies without real technological or business model progress. Firms in these economies are still in the early stages of DT, making immediate, tangible technological upgrades more influential than high-level strategic narratives.

Unlike its direct relationship with FV, DW does not significantly affect ESG performance. This result is theoretically plausible, aligning with the fundamental difference between the short-term nature of DW and the long-term trajectory of ESG outcomes. Operationally, scholars identify DW by applying yearly text mining techniques to annual reports and sustainability disclosures, allowing them to capture rhetorical or promotional shifts that occur during the annual reporting cycle (Saxena 2024; Lagasio 2024). By contrast, ESG scores and the behavioral inputs underlying them typically evolve over multi-year horizons and are measured through lagged, often third-party, data streams, making them structurally insensitive to short-term fluctuations in disclosure tone or terminology (Lagasio 2024; Saxena 2024). Consequently, symbolic digital narratives alone are unlikely to produce measurable improvements in ESG performance. This distinction also helps explain why theoretical mechanisms established for substantive DT cannot be directly extended to DW. Empirical evidence demonstrates that DT affects firms' ESG performance positively (Wang and Xia 2024; Xu et al. 2024), and a review of empirical studies on the link between DT and ESG further clarifies this distinction: only sustained and substantive digital investments—such as the long-term adoption of digital technologies or continuous digital innovation—generate persistent improvements in ESG performance (Wang and Xia 2024; Xu et al. 2024; Feng and Nie 2024).

Additionally, in this sample, ESG performance has no significant effect on FV. This result does not support prior research, which indicated that ESG performance can enhance a firm's reputation in investors' sight (Menon and Kahn 2003), improve efficiency at the labor and operational levels, and therefore increase capital market benefits (Dhaliwal et al. 2011). These results may be due to differences in the contexts of developing countries compared with developed ones. In particular, after being formally proposed in the United Nations Global Compact (2004), ESG-related policies have been actively implemented across developed countries, with certain countries having ESG and legal frameworks (Singhania et al. 2024), whereas in the context of developing countries, empirical evidence about ESG performance is limited due to inadequate legislation, penalties, and incentives for ESG practices, a lack of capability, and a preference for financial performance (Miralles-Quirós et al. 2018; Yoon et al. 2018; Naeem et al. 2022). However, this interpretation should be viewed cautiously, as our empirical analysis does not directly examine differences in investor preferences or institutional environments across countries.

However, this research indicates that ESG does not play a mediating role in the impact of DW on FV. This finding is opposite to prior research showing that ESG mediates the impact of DT on enterprises' high-quality innovation (Yang 2025) and the effect of DT on FV (Wang and Xia 2024). The result stems from DW being characterized by symbolic short-term signaling rather than substantive technological investment, as aforementioned. Therefore, the absence of a mediation effect is theoretically consistent: without real digital capabilities, firms lack structural, long-term changes required to improve ESG outcomes, even though DW may still generate a short-term direct impact on FV through impression management.

## 7. Conclusions and Implications

This study yields several key findings. Firstly, when considered as a composite structure, DW is positively related to FV; however, this effect is driven by only two of its components (digital technology adoption washing and business model innovation washing). Secondly, DW does not significantly influence ESG performance. Thirdly, ESG performance and its individual pillars do not have a significant direct impact on FV in the examined context. Finally, the empirical results demonstrate that ESG performance does not play a mediating role in the relationship between DW and FV.

This study makes theoretical contributions to the corporate disclosure and DT literature. It uniquely examines the direct effects of DW on FV by incorporating specific DW dimensions, which have not been comprehensively explored in prior studies. Additionally, by investigating the mediating role of ESG performance, this study expands current theoretical boundaries, revealing that ESG does not mediate the DW-FV relationship. Furthermore, the research provides updated empirical evidence from the ASEAN-4 and Vietnam contexts, filling a critical gap in the literature regarding the economic consequences of symbolic digital behaviors in emerging markets.

From a methodological perspective, this analysis contributes to the literature by integrating machine learning-assisted text mining with econometric panel data analysis. By developing a systematic keyword dictionary and utilizing predictive models to quantify the gap between digital commitments and actual actions in corporate annual reports, this research provides a novel, robust, and scalable measurement approach for identifying and quantifying symbolic digital disclosures.

The findings offer valuable practical implications for firm executives and investors. For firms, managers are encouraged to transition from symbolic DW to substantive DT. Enterprises should leverage digital tools to genuinely strengthen ESG data systems, operational transparency, and sustainability outcomes, ensuring that market valuation is supported by authentic organizational progress rather than rhetorical amplification. For investors, the results underscore the need for greater caution. Investors should critically evaluate the quality of digital sustainability disclosures by complementing corporate narratives with independent ESG data sources, third-party ratings, and substantive performance indicators, prioritizing firms with verifiable ESG improvements over those with digitally enhanced communication.

The comparative evidence from the ASEAN-4 countries and Vietnam offers important policy insights for sustainable digital development. Regulators and policymakers should consider strengthening standardized disclosure frameworks to prevent opportunistic digital reporting. Enhancing digital reporting assurance and developing stringent regulatory guidelines for AI-generated or digitally inflated sustainability content will be crucial to maintaining market integrity and protecting stakeholders in emerging economies.

The research still has limitations that future studies can address. Firstly, the sample of this research was limited to five developing countries in ASEAN; therefore, future research could expand the scope or focus on less developed countries. Secondly, due to limited time,

we investigated firms in over a short period from 2019 to 2024, while realizing the effects of sustainable development (ESG) requires a longer period to be clearly and measured. Finally, this research did not explore the differentiated impact across various enterprise types or different industries.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/risks14080183/s1.

**Author Contributions:** Conceptualization, A.T.D. and N.T.A.T.; methodology, A.T.D. and P.B.N.L.; software, T.T.H.T. and H.G.T.; validation, H.A.L. and N.T.A.T.; formal analysis, T.T.H.T., H.A.L., N.T.A.T. and H.G.T.; investigation, A.T.D. and N.T.A.T.; resources, H.A.L., H.G.T. and N.T.A.T.; data curation, A.T.D., P.B.N.L. and H.G.T.; writing—original draft preparation, A.T.D., P.B.N.L., T.T.H.T., H.G.T., H.A.L. and N.T.A.T.; writing—review and editing, A.T.D. and P.B.N.L. All authors have read and agreed to the published version of the manuscript.

**Funding:** This paper was supported by National Economics University, 207 Giai Phong, Hanoi, Vietnam. [Grant number: Project coded B2024.KHA.09].

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author due to the large dataset and its use for ongoing further research. In addition, some restrictions apply to the availability of these data. The data were obtained from Bloomberg and are available from https://www.bloomberg.com/ (accessed on 20 December 2025) with the permission of Bloomberg.

**Acknowledgments:** The authors would like to thank the editor and the anonymous reviewers for their valuable comments on our submission.

**Conflicts of Interest:** The authors declare no conflicts of interest.

## Abbreviations

The following abbreviations are used in this manuscript:

| | |
|---|---|
| AA | Digital technologies adoption action |
| AI | Artificial intelligence |
| API | Application programming interface |
| ASEAN | Association of Southeast Asian Nations |
| AW | Digital technology adoption washing |
| BM | Book-to-market ratio |
| CSR | Corporate social responsibility |
| DT | Digital transformation |
| DTA | DT actions |
| DTW | DT words/digital transformation commitment |
| DW | Digital washing |
| E | Environmental |
| ESG | Environmental, social, and governance |
| FE | Fixed effects |
| FV | Firm value |
| G | Governance |
| H | Hypothesis |
| ICT | Information communication and technologies |
| IMA | Digital strategy implementation action |
| IMW | Digital strategy implementation washing |
| INA | Business model innovation action |
| INW | Business model innovation washing |
| LEV | Leverage |
| MSE | Mean squared error |
| OLS | Ordinary least squares |

| | |
|---|---|
| RBV | Resource-based view theory |
| RE | Random effects |
| RMSE | Root mean squared error |
| ROA | Return on assets |
| S | Social |
| SIZE | Size (natural logarithm of total corporate assets) |
| TPB | Theory of planned behavior |
| VIF | Variance inflation factor |

## Appendix A

**Table A1.** Prediction model.

| Predicted Year | Targeted Variable | Coefficient | R-Square | RMSE | MSE | *p*-Value |
|---|---|---|---|---|---|---|
| 2019 | AAf | 0.7026 | 0.2706 | 0.0006 | 0.0000 | 0.00000075723 |
| | INAf | 0.6768 | 0.3122 | 0.0006 | 0.0000 | 0.00000007120 |
| | IMAf | 0.6815 | 0.1045 | 0.0009 | 0.0000 | 0.00344010000 |
| | DTAf | 0.7092 | 0.3499 | 0.0015 | 0.0000 | 0.00000000755 |
| 2020 | AAf | 0.6246 | 0.2893 | 0.0020 | 0.0000 | 0.00000026738 |
| | INAf | 0.9787 | −0.1531 | 0.0007 | 0.0000 | 1 |
| | IMAf | 0.5822 | 0.4478 | 0.0009 | 0.0000 | 0.00000000001 |
| | DTAf | 0.7668 | 0.3728 | 0.0028 | 0.0000 | 0.00000000181 |
| 2021 | AAf | 0.8551 | 0.3843 | 0.0006 | 0.0000 | 0.00000000041 |
| | INAf | 0.6634 | 0.3456 | 0.0005 | 0.0000 | 0.00000000513 |
| | IMAf | 0.5030 | 0.4125 | 0.0007 | 0.0000 | 0.00000000006 |
| | DTAf | 0.6765 | 0.4325 | 0.0014 | 0.0000 | 0.00000000001 |
| 2022 | AAf | 0.7694 | 0.3344 | 0.0020 | 0.0000 | 0.00000000362 |
| | INAf | 0.6855 | 0.6323 | 0.0006 | 0.0000 | 0.00000000000 |
| | IMAf | 0.6239 | 0.4978 | 0.0011 | 0.0000 | 0.00000000000 |
| | DTAf | 0.7030 | 0.4568 | 0.0030 | 0.0000 | 0.00000000000 |
| 2023 | AAf | 0.7905 | 0.7054 | 0.0005 | 0.0000 | 0.00000000000 |
| | INAf | 0.8943 | 0.0285 | 0.0005 | 0.0000 | 0.11385000000 |
| | IMAf | 0.5856 | 0.1951 | 0.0008 | 0.0000 | 0.00001467700 |
| | DTAf | 0.7735 | 0.4084 | 0.0014 | 0.0000 | 0.00000000002 |
| 2024 | AAf | 0.9744 | 0.6440 | 0.0007 | 0.0000 | 0.00000000000 |
| | INAf | 0.7420 | 0.6899 | 0.0005 | 0.0000 | 0.00000000000 |
| | IMAf | 0.6698 | 0.6326 | 0.0010 | 0.0000 | 0.00000000000 |
| | DTAf | 0.7942 | 0.7432 | 0.0017 | 0.0000 | 0.00000000000 |

**Table A2.** Model diagnostics for integrated models (7 and 8).

| Diagnostics Type | Diagnostics Name | Model 7 | Model 8 | Results |
|---|---|---|---|---|
| Model selection | Breusch–Pagan | $\chi^2(01) = 1025.31$ *** | $\chi^2(01) = 1061.00$ *** | Choose RE |
| | Hausman | $\chi^2(5) = 63.05$ *** | $\chi^2(7) = 31.72$ *** | Choose FE |
| Deficiency diagnosis | Multicollinearity | Mean VIF = 1.04 | Mean VIF = 2.95 | No multicollinearity |
| | Heteroskedasticity | $\chi^2(16) = 167.640$ *** | $\chi^2(29) = 205.220$ *** | Heteroskedasticity |
| | Autocorrelation | F(1, 442) = 0.260 | F(1, 442) = 0.293 | No autocorrelation |
| | Cross-sectional dependence | Exist *p*-value < 0.05 | Exist *p*-value < 0.05 | Cross-sectional dependence |

***: *p*-value < 0.001.

## Appendix B

**Table A3.** Correlation matrix.

| | DW | AW | INW | IMW | ESG | E | S | G | FV | BM | LEV | ROA | SIZE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DW | 1.0000 | | | | | | | | | | | | |
| AW | 0.8296 *** | 1.0000 | | | | | | | | | | | |
| INW | 0.7273 *** | 0.8648 *** | 1.0000 | | | | | | | | | | |
| IMW | 0.7911 *** | 0.9372 *** | 0.9202 *** | 1.0000 | | | | | | | | | |
| ESG | −0.0266 | −0.0250 | −0.0226 | −0.0135 | 1.0000 | | | | | | | | |
| E | 0.0021 | 0.0079 | 0.0138 | 0.0211 | 0.7603 *** | 1.0000 | | | | | | | |
| S | −0.1076 *** | −0.1210 *** | −0.1104 *** | −0.1053 *** | 0.6615 *** | 0.1884 *** | 1.0000 | | | | | | |
| G | 0.0109 | 0.0234 | 0.0244 | 0.0058 | 0.3948 *** | 0.1593 *** | 0.1090 *** | 1.0000 | | | | | |
| FV | 0.4262 *** | 0.4884 *** | 0.4321 *** | 0.4659 *** | −0.0274 | −0.0187 | −0.0905 *** | −0.0101 | 1.0000 | | | | |
| BM | −0.3737 *** | −0.4172 *** | −0.3710 *** | −0.3987 *** | −0.1001 *** | −0.1039 *** | 0.0074 | 0.0003 | −0.3025 *** | 1.0000 | | | |
| LEV | −0.0955 *** | −0.1493 *** | −0.1263 *** | −0.1422 *** | 0.0569 ** | −0.0251 | 0.0572 ** | 0.0209 | −0.0558 | −0.0330 | 1.0000 | | |
| ROA | 0.3289 | 0.4579 | 0.4106 | 0.4414 | 0.0038 | 0.0554 | −0.0800 | 0.0041 | 0.3238 | −0.3335 | −0.2425 | 1.0000 | |
| SIZE | −0.2302 *** | −0.2617 *** | −0.2427 *** | −0.2548 *** | 0.1382 *** | 0.1168 *** | 0.2231 *** | −0.1118 *** | −0.2259 *** | 0.1335 *** | 0.2537 *** | −0.1604 *** | 1.0000 |

***: $p$-value < 0.001; **: $p$-value < 0.05.

**Table A4.** Robustness tests.

| **Direct Effects** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **FV (1)** | **FV (2)** | **ESG (3)** | **E (4)** | **S (5)** | **G (6)** | **FV (7)** | **FV (8)** |
| DW | 0.5616976 ***<br>(19.77) | | 0.00000000000190<br>(1.14) | | | | 0.5616976 ***<br>(19.77) | |
| AW | | 30.87132 ***<br>(12.81) | | −0.0000000000446<br>(−0.49) | 0.0000000000255<br>(0.49) | 0.000000000109<br>(0.83) | | 30.87132 ***<br>(12.81) |
| INW | | 4.053201 **<br>(1.97) | | −0.000000000229<br>(−1.16) | −0.0000000000819<br>(−1.03) | 0.000000000298<br>(1.17) | | 4.053201 **<br>(1.97) |
| IMW | | 1.323758<br>(0.40) | | 0.000000000147<br>(1.10) | −0.0000000000182<br>(−0.54) | −0.000000000246<br>(−1.18) | | 1.323758<br>(0.40) |
| ESG | | | | | | | 0.7372905<br>(1.47) | |
| E | | | | | | | | |
| S | | | | | | | | |
| G | | | | | | | | 0.6745073<br>(1.71) |
| BM | −0.4844322 ***<br>(−42.19) | −0.4839335 ***<br>(−43.60) | 0.00000000000158<br>(1.36) | −0.00000000000192<br>(−1.36) | −0.00000000000092<br>(−1.36) | 0.00000000000258<br>(1.37) | −0.4844322 ***<br>(−42.19) | −0.4839335 ***<br>(−43.60) |
| LEV | −0.0896616 **<br>(−6.43) | −0.0895055 **<br>(−6.46) | −0.000000000000163<br>(−0.73) | 0.000000000000173<br>(0.62) | 0.000000000000218<br>(1.17) | −0.00000000000008<br>(−0.24) | −0.0896616 **<br>(−6.43) | −0.0895055 **<br>(−6.46) |
| ROA | 0.015814 **<br>(6.08) | 0.0162091 **<br>(6.14) | −0.000000000000122<br>(−0.86) | 0.000000000000136<br>(0.77) | 0.000000000000070<br>(0.77) | −0.00000000000019<br>(−0.82) | 0.015814 **<br>(6.08) | 0.0162091 **<br>(6.14) |
| SIZE | 0.8736007 ***<br>(9.68) | 0.8680598 ***<br>(9.77) | 0.0000000000555<br>(1.44) | −0.0000000000716<br>(−1.44) | −0.0000000000368<br>(−1.44) | 0.0000000000914<br>(1.44) | 0.8736007 ***<br>(9.68) | 0.8680598 ***<br>(9.77) |
| Fixed year effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 2527 | 2527 | 2527 | 2527 | 2527 | 2527 | 2527 | 2527 |
| R-square (within) | 0.7091 | 0.7078 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.7091 | 0.7078 |
| F-statistics | (10, 5)<br>6621.23 | (12, 5)<br>3274.94 | (10, 5)<br>-- | (12, 5)<br>-- | (12, 5)<br>-- | (12, 5)<br>-- | (10, 5)<br>9654.38 | (12, 5)<br>1928.99 |

**Table A4.** *Cont.*

| **Direct Effects** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **FV (1)** | **FV (2)** | **ESG (3)** | **E (4)** | **S (5)** | **G (6)** | **FV (7)** | **FV (8)** |
| Indirect effects | | | | | | | |
| Model | | | Path | | Observed coefficient | | *p*-value | |
| Model 7 | | | DW => ESG => FV | | −0.0002713 | | 0.849 | |
| | | | Total indirect effect | | 5,360,000,000 | | 0.031 | |
| Model 8 | | | AW => E => FV | | −0.1302019 | | 0.591 | |
| | | | AW => S => FV | | 0.4066904 | | 0.275 | |
| | | | AW => G => FV | | −0.0079233 | | 0.984 | |
| | | | INW => E => FV | | −0.0623655 | | 0.860 | |
| | | | INW => S => FV | | 0.3755963 | | 0.531 | |
| | | | INW => G => FV | | −0.0125498 | | 0.978 | |
| | | | IMW => E => FV | | 0.2134685 | | 0.637 | |
| | | | IMW => S => FV | | −0.6232216 | | 0.301 | |
| | | | IMW => G => FV | | 0.022205 | | 0.976 | |
| | | | Total indirect effect | | 0.181698 | | 0.644 | |

*** *p*-value < 0.001; **: *p*-value < 0.05.

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