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Digital Transformation and ESG Synergy in Enhancing Enterprise Market Value

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Abstract

Coordinating digital transformation with environmental, social, and governance (ESG) practices is essential for corporate sustainability. Examining how this coordination affects enterprise market value clarifies the value implications of integrating the two strategies. Drawing on 26,486 firm–year observations for Chinese A-share firms during 2011–2024, this study constructs a digital transformation–ESG synergy (DESG) index using a coupling coordination degree (CCD) model that integrates annual-report digital transformation frequency and Huazheng ESG performance scores. A two-way fixed-effects model is used for estimation. The reported baseline shows a significant positive association between DESG and enterprise market value after controlling for firm characteristics and firm and year fixed effects. First-link mechanism analysis indicates that DESG is positively associated with firms' internal conversion capacities (absorptive, innovation, and adaptive capabilities), operational green transformation, and external corporate reputation. Moderation analysis further shows that all five internal and external moderators positively shift the marginal DESG–market value slope: media coverage and green governance recognition amplify the positive association across all quartiles, whereas entrepreneurial spirit, new quality productive forces, and analyst attention exhibit threshold effects in which the marginal slope shifts from negative or null in the lowest quartile to significantly positive at the median and upper quartiles. Heterogeneity analysis further reveals that this association is more pronounced in eastern and central China and among high-technology, state-owned, and large firms. The findings provide firm-level evidence on the market value implications of digital–ESG synergy and offer theoretical and managerial implications for coordinating the two strategies.

Keywords: digital transformation; ESG; coupling coordination; enterprise market value; dynamic capabilities; information attention

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1. Introduction

Firms now face a dual strategic mandate: they must become digitally capable while demonstrating credible environmental, social, and governance (ESG) responsibility [1–4]. Although each agenda can support long-term competitiveness, pursuing them simultaneously does not ensure that they operate as a coherent value-creating system. Digital technologies reshape how firms acquire information, allocate resources, and organize production, whereas ESG practices orient corporate decisions toward environmental responsibility, stakeholder interests, and accountable governance [1,2]. Parallel adoption may therefore create mutually reinforcing resources, but it may also produce fragmented

systems, competing priorities, and implementation costs when progress in one domain is not matched by progress in the other [3,4]. For investors, the relevant issue is not simply whether firms pursue both agendas but whether their coordinated development carries market value relevance.

The potential complementarity between the two agendas provides a strong basis for examining this question. Digital transformation supplies data infrastructure, analytical capacity, automation, and connectivity that can improve the traceability and execution of ESG activities. ESG practices, in turn, provide strategic direction, governance discipline, and stakeholder orientation that can channel digital investment toward material and long-term objectives [1,5]. Firm-level evidence increasingly links digital transformation to stronger ESG performance and broader sustainable development outcomes [6–9]. Nevertheless, coexistence does not necessarily imply coordination. Digital and ESG systems differ in their objectives, time horizons, organizational ownership, and evaluation criteria, so their joint value depends on how coherently they develop together. In this study, digital transformation–ESG synergy (DESG) denotes this state of coupling coordination and mutual reinforcement between a firm's digital transformation and ESG subsystems, measured through the coupling coordination degree (CCD) model rather than a simple additive sum or a conventional linear interaction. China provides a particularly revealing setting because listed firms are simultaneously deepening digital transformation and responding to increasingly salient ESG expectations [6,7,9,10].

Research on digital transformation shows that data-driven technologies reshape information processing, operational efficiency, human capital, supply chain resilience, and firm value [2,11–15]. This work clarifies how digital capabilities alter resource allocation, organizational functioning, and capital-market outcomes, but it generally treats digital transformation as the focal strategic input. It therefore cannot establish whether investors value digital progress more highly when it develops in step with ESG practices.

A parallel literature links ESG practices to financing conditions, innovation, stakeholder trust, corporate reputation, financial performance, and market valuation [1,16–22]. It also shows that these returns depend on organizational capabilities and institutional conditions. Yet analyses centered on ESG levels do not reveal whether ESG creates greater market value when supported by commensurate digital capability. Taken together, the two streams establish the economic relevance of each agenda without making their coordinated development the focal empirical object.

A growing set of studies has begun to connect the two domains. Existing research examines interaction effects between digital technology application and ESG in explaining corporate performance [23], digital–green synergy in relation to ESG outcomes [24], and the broader opportunities and tensions associated with twin digital and sustainable transitions [3,4]. Most closely related to the present study, Sun et al. use a coupling coordination framework to investigate how digital transformation and ESG jointly contribute to corporate decarbonization [10]. Related evidence links digital transformation to firm value through capability formation under ESG-related conditions [15]. These advances demonstrate that the two agendas are interdependent, but the enterprise market value implications of their coordinated development remain underexamined. Some studies operationalize joint effects through linear product terms, whereas others examine environmental or ESG outcomes; our study examines how digital–ESG synergy—measured via the coupling coordination degree (CCD) model—enhances enterprise market value and how internal organizational conversion and external market recognition shape this synergistic value creation process.

Addressing this valuation question requires an integrated theoretical narrative rather than a disconnected list of mediating and moderating factors. Drawing on resource complementarity, dynamic capabilities, and signaling theory [25–27], we organize the link between

DESG and enterprise market value into a unified three-stage value creation chain: (i) internal organizational conversion, (ii) external stakeholder recognition, and (iii) internal and external boundary conditioning. Specifically, coordinated digital–ESG inputs do not automatically translate into market capitalization; firms must first convert strategic synergy into internal absorptive, innovation, and adaptive capabilities [15,28–31] and deploy them into concrete operational green transformation [32–35]. Because external investors face information asymmetry regarding internal transformation, these operational gains must also be translated into credible external corporate reputation [22,36–39] to be priced into market value. Furthermore, the effectiveness of this conversion-and-recognition chain is contingent on two boundary domains: internal implementation capacity—shaped by leadership agency (entrepreneurial spirit and executive green governance recognition) and the firm's socio-technical productive base (new quality productive forces) [40–45]—and external information intermediation via media coverage and securities analyst attention [46–48]. Accordingly, this study asks three questions: How is DESG associated with enterprise market value? Through which capability, operational, and reputational channels is its value relevance formed? Under what internal, external, and firm-specific boundary conditions does this relationship hold or shift?

To answer these questions, the empirical analysis draws on 26,486 firm–year observations from Chinese A-share listed companies over the 2011–2024 period. Adapting the coupling coordination framework of Sun et al. [10], we construct the DESG coupling coordination index from firms' digital transformation keyword frequencies and Huazheng ESG ratings, as detailed in Section 3.2.2. Firm and year fixed-effects models estimate the baseline DESG–enterprise market value relationship, followed by extensive robustness and endogeneity checks. The subsequent analysis evaluates moderating and heterogeneous boundary conditions and, following Jiang's [49] mechanism approach, estimates whether DESG is associated with absorptive, innovation, and adaptive capabilities, green transformation, and corporate reputation.

The analysis yields four principal findings. First, DESG is positively associated with enterprise market value. Second, DESG is positively associated with firms' absorptive, innovation, and adaptive capabilities, green transformation, and corporate reputation. Third, all five internal and external moderators exhibit positive interaction effects with DESG, revealing a nuanced boundary structure: media coverage and green governance recognition consistently amplify the positive DESG–market value slope across all quartiles, whereas entrepreneurial spirit, new quality productive forces, and analyst attention act as threshold conditions under which the marginal DESG slope transitions from negative or statistically insignificant in the lowest quartile (P25) to significantly positive at the median (P50) and upper quartile (P75). Finally, the positive relationship is evident in eastern and central China but not statistically significant in western China, and it is more pronounced among high-technology, state-owned, and large firms, whereas pollution industry status does not produce a significant structural difference.

This study contributes to three related strands of the literature. First, it advances research on digital transformation and ESG by shifting the focal explanatory construct from their separate firm-level effects to their coordinated development as a strategic configuration. By applying the coupling coordination degree (CCD) model to capture both the coupling interaction strength and the comprehensive development level of digital transformation and ESG governance, DESG operationalizes strategic synergy and distinguishes coordinated development from standalone component effects. Second, it develops an integrated three-stage account of value formation that connects strategic resource configuration (DESG) with internal capability conversion (absorptive, innovation, and adaptive capabilities), operational reconfiguration (green transformation), and external capital-market recognition

(corporate reputation). Consistent with the first-link mechanism design [49], the empirical analysis documents how DESG relates to each organizational outcome while drawing on the established valuation literature for their downstream market value links. Third, it integrates internal implementation conditions (leadership agency and productive foundations), external information-attention conditions (media and analyst scrutiny), and firm heterogeneity within a unified boundary framework, demonstrating why dual digital–ESG transformation requires sufficient internal productive capacity and external information intermediation to overcome initial adjustment costs and generate positive market valuation.

The remainder of this article proceeds as follows. Section 2 develops the theoretical mechanisms and hypotheses. Section 3 describes the research design, Section 4 reports the empirical results, and Section 5 presents the discussion and conclusions.

2. Theoretical Background and Research Hypotheses

2.1. Theoretical Foundation

Explaining why coordinated digital transformation and ESG development can create enterprise market value requires a framework that connects resource configuration with organizational conversion and capital-market recognition. Resource complementarity provides the central logic. The resource-based view regards firm-specific assets and capabilities as sources of sustained advantage [26], while complementarity research shows that heterogeneous resources can produce greater joint value when their uses reinforce one another [25,27]. DESG applies this logic to two strategic systems whose value depends on how coherently they develop.

Digital transformation supplies data infrastructure, analytical capacity, automation, and connectivity; ESG practices supply sustainability objectives, governance disciplines, and stakeholder orientation. These resource sets address different organizational bottlenecks. Digital technologies can make ESG objectives measurable and operational, while ESG priorities can guide digital investment toward material long-term problems. Their coordinated development can therefore reduce resource misallocation and create a strategic configuration that neither system can provide alone [2–4].

These complementary functions can enhance expected cash flows, expand growth options, and mitigate operational and regulatory risk, providing a clear economic rationale for examining how digital transformation and ESG synergy enhances enterprise market value. However, because integrating digital architecture with ESG governance entails nontrivial organizational adjustment costs, translating digital transformation and ESG synergy into enterprise market value requires a sequential chain of internal capability conversion, operational execution, and external market recognition.

To avoid a fragmented proliferation of variables, our theoretical framework integrates the mediating mechanisms and moderating boundary conditions into a single coherent architecture (illustrated in Figure 1). First, at the internal conversion stage, dynamic capabilities explain how firms absorb external technological and sustainability knowledge (absorptive capability), recombine resources into new processes and products (innovation capability), and realign organizational routines (adaptive capability) [28,29]. Second, at the operational execution stage, green transformation captures the concrete deployment of these capabilities into clean production, pollution abatement, and environmental monitoring. Third, at the external valuation stage, corporate reputation captures how stakeholders and capital-market participants evaluate the credibility of a firm's conduct [36,37]. Thus, dynamic capabilities, green transformation, and corporate reputation are not three isolated theories; rather, they represent the internal capability engine, the operational output, and the external market bridge through which DESG is converted into enterprise market value.

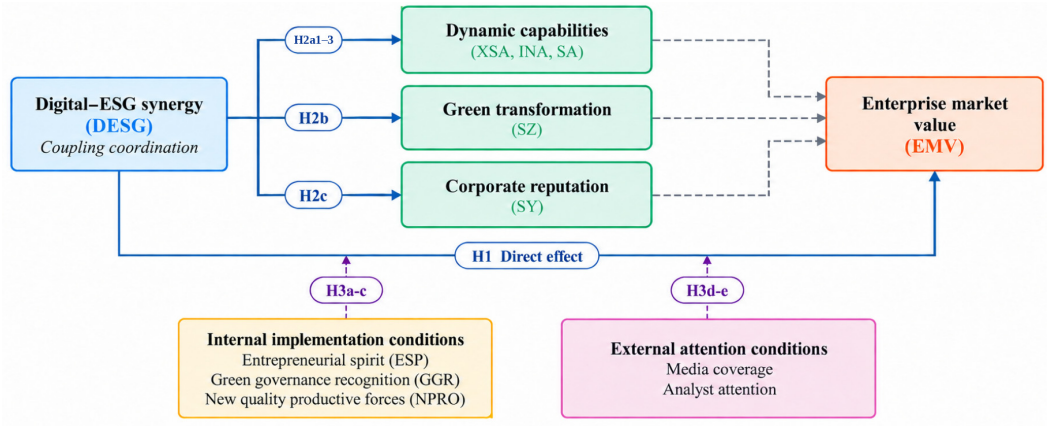

Figure 1. Conceptual framework of the proposed relationships. Notes: Figure 1 illustrates the integrated three-stage theoretical framework linking strategic resource configuration (DESG) to enterprise market value (EMV) through internal capability conversion (H2a1–H2a3), operational green transformation (H2b), and external corporate reputation (H2c), conditioned by internal implementation foundations (H3a–H3c) and external information attention (H3d–H3e). Following Jiang [49], the mechanism analysis in Section 4.4 estimates the first-stage links from DESG to each mechanism variable, while dashed arrows denote downstream valuation links established in the prior literature.

Correspondingly, the five moderating variables are selected specifically to govern the two critical transitions in this value chain: internal implementation and external market pricing. On the internal side, upper echelons theory indicates that strategic resource conversion depends on top managers' risk-taking propensity and long-term resource commitment (entrepreneurial spirit, ESP) as well as their cognitive prioritization of environmental stewardship (green governance recognition, GGR) [40,41], while new quality productive forces (NPRO) provide the skilled human capital and digital–intelligent physical infrastructure required to execute coordinated transformation at scale [44,45]. On the external side, information–intermediation theory indicates that capital-market pricing depends on public dissemination and scrutiny (media coverage) and professional financial interpretation (analyst attention) [46,48]. Together, the three internal moderators govern whether DESG is effectively implemented inside a firm, while the two external moderators govern whether it is legibly priced by external investors.

2.2. Digital Transformation and Enterprise Market Value

Digital transformation changes how firms acquire information, coordinate activities, and design products and processes. Digital infrastructure and analytics can reduce transaction and coordination costs, improve decision speed, and support business model renewal [2]. These changes improve operating efficiency and expand future growth options, both of which can increase investors' expectations of cash flows and resilience. Digital transformation thus has a plausible positive relationship with enterprise market value.

Empirical research supports several parts of this value logic. Studies of Chinese listed firms associate digital transformation with greater stock liquidity, human capital restructuring, and supply chain integration and resilience [11–13]. Related evidence connects digital transformation with firm value and shows that ESG conditions and information interaction shape the conversion of digital investment into valuation gains [14,19]. The literature therefore identifies digital transformation as an important value-generating resource while also showing that complementary organizational and strategic conditions shape its valuation consequences.

Digital investment can nevertheless fail to produce durable market value when it is costly, fragmented, or weakly connected to corporate objectives. Complementary skills,

organizational redesign, and sustained managerial attention are needed to convert technology spending into productive capabilities, helping explain the digital productivity paradox and uneven firm outcomes [2]. Research on digital sustainability and the twin transition likewise documents synergies alongside implementation tensions [3,4]. Its value potential is more likely to be realized when a strategic framework directs where technology should be applied and how its benefits should be governed.

2.3. ESG Practices and Enterprise Market Value

ESG practices provide strategic direction by embedding environmental, social, and governance concerns in corporate decisions. Strong ESG systems can lower exposure to regulatory, operational, and reputational risks, strengthen stakeholder relationships, and support innovation and access to long-horizon capital [16,18,20]. By improving expected cash flows and reducing risk premia, these outcomes can raise enterprise market value.

The ESG–value relationship, however, is not uniform. Evidence varies across ESG dimensions, institutional settings, and firm characteristics [17,18]. ESG controversies can erode corporate performance, while governance arrangements and substantive ESG practices may buffer that damage [21]. Variation in implementation depth and information quality can also make it difficult for investors to distinguish embedded sustainability practices from symbolic compliance. ESG therefore creates value most reliably when commitments are credible and can be translated into operating decisions.

Digital capabilities can address these constraints by improving data collection, monitoring, internal coordination, and external disclosure. Conversely, ESG priorities can prevent digital transformation from becoming detached from material environmental and stakeholder objectives. Recent studies find that digital transformation improves ESG performance and sustainable development [6,7,9], but the central issue here is whether the two systems develop in a mutually reinforcing and synergistic manner. This shifts the inquiry from the standalone effects of digital transformation or ESG to how digital transformation and ESG synergy enhances enterprise market value.

2.4. DESG as a Synergistic Value Creation Strategy

DESG captures the coupling coordination synergy between a firm's digital transformation and ESG subsystems. From a systems perspective, coupling coordination reflects both the strength of reciprocal interaction between the two subsystems and the balance of their coordinated development [10,24]. A higher DESG level therefore indicates greater scope for the two strategic systems to reinforce one another; it does not simply represent the sum of two standalone investments.

Reciprocal reinforcement can occur in both directions. ESG objectives guide the allocation of digital resources toward traceable sustainability priorities, while digital systems improve the timeliness, verifiability, and operational use of ESG information. This alignment can reduce duplicated investment, improve responses to stakeholder and regulatory demands, and make a firm's long-term strategy more credible. The resulting gains in resource efficiency, risk control, growth opportunities, and information quality provide the economic basis for a DESG valuation premium [5–7,9].

Existing studies establish the interdependence between digital transformation and ESG performance, yet how their coupling coordination synergy enhances enterprise market value requires direct empirical investigation. Interaction-based evidence shows that digital technology application and ESG performance jointly improve corporate performance [23], and related studies report that digital transformation conditions the ESG–performance relationship [14,19]. Coupling-based research links digital–ESG coordination to lower carbon intensity and stronger ESG outcomes [10,24], while recent evidence connects digital

transformation, capability formation, ESG conditioning, and firm value [15]. Building on these insights, we examine whether coupling-based digital transformation and ESG synergy (DESG) directly enhances enterprise market value, and propose:

H1. *Digital transformation and ESG synergy (DESG) has a positive effect on enterprise market value.*

2.5. Value Formation Mechanisms

As outlined in our theoretical foundation, the value creation process linking DESG to enterprise market value unfolds across three interconnected organizational domains: internal capability conversion (dynamic capabilities: XSA, INA, and SA), operational reconfiguration (green transformation: SZ), and external stakeholder recognition (corporate reputation: SY). Following the mechanism-testing framework of Jiang [49], Hypotheses H2a1–H2a3, H2b, and H2c evaluate the first-stage links from DESG to each organizational mechanism variable, while the established empirical literature [15,22,30,31,34,38,39] grounds their downstream valuation relevance.

2.5.1. Dynamic Capabilities

Dynamic capabilities enable firms to sense changes, seize opportunities, and reconfigure resources as competitive and institutional conditions evolve [28,29]. Absorptive capability supports the recognition and use of external knowledge; innovation capability converts knowledge and resources into new products and processes; and adaptive capability enables a firm to revise routines and strategic responses. These capabilities are associated with stronger organizational performance and value creation because they expand growth options and reduce the costs of environmental uncertainty [15,30,31,50].

DESG should reinforce all three dimensions. Digital systems enlarge the speed and scope of information search, while ESG broadens the knowledge set to include environmental, regulatory, and stakeholder signals, strengthening absorptive capability [32]. Digital experimentation guided by ESG objectives directs innovation toward commercially and socially relevant applications [33]. Real-time monitoring and stakeholder feedback also help firms adjust operations as technologies and institutional demands change, strengthening adaptive capability [29]. Coordinated digital and ESG development should therefore improve a firm's capacity to learn, innovate, and adapt.

H2a1. *DESG is positively associated with firms' absorptive capability.*

H2a2. *DESG is positively associated with firms' innovation capability.*

H2a3. *DESG is positively associated with firms' adaptive capability.*

2.5.2. Green Transformation

Green transformation converts environmental objectives into changes in technologies, production processes, resource use, pollution control, and monitoring. Such changes can reduce operating and environmental liability costs, improve policy compatibility, and create market opportunities for green products. Evidence from Chinese listed manufacturers links low-carbon transition to enterprise value, establishing the value relevance of this operational pathway [34].

DESG creates favorable conditions for this transformation because its two components supply complementary inputs. Digital technologies make resource use and environmental performance more visible, traceable, and manageable; ESG provides the targets, accountability, and governance routines needed to act on that information. Evidence connecting

digital transformation with ESG improvement, green innovation, and carbon reduction is consistent with this logic [6,7,10,33]. Stronger coordination should thus help firms convert sustainability commitments into documented green transformation activity.

H2b. *DESG promotes firms' green transformation.*

2.5.3. Corporate Reputation

Corporate reputation summarizes stakeholders' accumulated judgments about a firm's reliability, quality, and strategic credibility [35]. A strong reputation can reduce information asymmetry, sustain stakeholder support, and improve long-term financial performance and shareholder value [38,39]. Recent evidence from China also identifies reputation as a value-relevant channel through which ESG performance is reflected in firm value [22].

DESG should improve reputation by making a firm's strategic commitments more coherent and verifiable. Digital systems enhance the traceability and timeliness of ESG information, while sustained ESG practices show that digital investment is directed toward responsible long-term objectives. When the two systems develop in coordination, stakeholders receive a more credible signal than either isolated disclosure or standalone technology investment can provide [36]. This consistency should strengthen evaluations of corporate reliability and strategic quality.

H2c. *DESG improves corporate reputation.*

2.6. Internal and External Boundary Conditions

The market value implications of DESG also depend on whether firms possess the internal foundations to implement dual transformation and whether external market participants can evaluate it. Entrepreneurial spirit (ESP), green governance recognition (GGR), and new quality productive forces (NPRO) govern internal strategic execution, whereas media coverage (Media) and analyst attention (ANALY) govern external information dissemination and valuation scrutiny. Importantly, when internal implementation foundations or external analyst coverage are weak, pursuing digital and ESG initiatives simultaneously may impose high upfront adjustment costs or face investor skepticism, yielding null or negative marginal valuation returns; stronger internal and external boundary conditions should therefore shift the marginal DESG–EMV slope upward.

2.6.1. Internal Implementation Conditions

Entrepreneurial spirit reflects a managerial orientation toward opportunity recognition, innovation, and calculated risk-taking [51,52]. Managers with stronger entrepreneurial spirit are more willing to commit resources to long-horizon initiatives, coordinate across organizational boundaries, and tolerate experimentation during digital and ESG integration. Evidence from Chinese firms indicates that entrepreneurial spirit reinforces the performance consequences of digital transformation and supply chain integration [42], while recent research links sustainable entrepreneurial orientation with ESG outcomes through data-driven and green technology innovation [43]. These behaviors should help firms turn DESG into market-recognized value.

H3a. *Entrepreneurial spirit positively moderates the relationship between DESG and enterprise market value, such that the marginal valuation slope of DESG becomes more positive as entrepreneurial spirit increases.*

Green governance recognition reflects executives' understanding of environmental issues and their willingness to treat sustainability as a strategic priority. Upper echelons

theory predicts that managerial values and cognitive frames influence how firms interpret external demands and allocate resources [40,41]. Stronger green governance recognition should encourage executives to embed ESG objectives in digital investment, performance systems, and operating decisions, reducing the risk that the two strategies remain disconnected. It should therefore strengthen the value effect of DESG.

H3b. *Green governance recognition positively moderates the relationship between DESG and enterprise market value, such that the marginal valuation slope of DESG becomes more positive as green governance recognition increases.*

New quality productive forces represent a technological and production foundation for implementing coordinated strategy at scale. Artificial intelligence capability and digital–intelligent transformation can strengthen this foundation by supporting advanced technologies, data use, and innovation-oriented production [44,45]. When new quality productive forces are stronger, compatible infrastructure, skills, and production systems allow digital and ESG resources to reinforce each other more efficiently. A weak foundation, by contrast, constrains the conversion of measured coordination into operational and market value.

H3c. *New quality productive forces positively moderate the relationship between DESG and enterprise market value, such that the marginal valuation slope of DESG becomes more positive as new quality productive forces increase.*

2.6.2. External Information Attention

Media coverage increases the public visibility of corporate conduct and adds third-party scrutiny. It can disseminate information about coordinated digital and ESG practices, compare corporate claims with observable actions, and impose reputational discipline [46]. Evidence from Chinese listed firms indicates that media attention strengthens the financial returns to ESG performance by improving transparency, stakeholder monitoring, and reputational incentives [47]. For firms with stronger DESG, greater coverage should make credible coordination easier for investors and other stakeholders to recognize, amplifying its valuation effect.

H3d. *Media coverage positively moderates the relationship between DESG and enterprise market value, such that the marginal valuation slope of DESG becomes more positive as media coverage increases.*

Analyst attention provides a different form of information intermediation. Securities analysts interpret complex strategic investments and reduce investors' information acquisition and processing costs [48]. Because DESG combines technological and sustainability information, professional coverage can help the market assess whether coordinated development is substantive and economically relevant. Greater analyst attention should therefore make the value content of DESG more legible and more likely to enter market prices.

H3e. *Analyst attention positively moderates the relationship between DESG and enterprise market value, such that the marginal valuation slope of DESG becomes more positive as analyst attention increases.*

Figure 1 summarizes the proposed direct relationship, value formation mechanisms, and internal and external boundary conditions.

3. Research Design

3.1. Sample and Data Sources

This study constructs a firm–year panel of Chinese A-share companies listed on the Shanghai and Shenzhen stock exchanges from 2011 to 2024. Corporate annual reports are obtained from CNINFO for textual analysis, patent records are retrieved from the Tonghuashun database, financial and corporate governance data are sourced from the CSMAR and Wind databases, and ESG performance is measured using the Sino-Securities (Huazheng) comprehensive ESG score.

Following standard sample selection criteria in Chinese capital-market research, we exclude financial sector firms, firms designated as ST or *ST, and observations with missing data on core variables, yielding a final panel sample of 26,486 firm–year observations across 3084 listed firms from 2011 to 2024.

To mitigate the influence of extreme outliers, continuous financial control variables are winsorized at the 1st and 99th percentiles within each year.

3.2. Variable Measurement

3.2.1. Dependent Variable

Enterprise market value (EMV), the dependent variable, is measured by the firm's annual A-share market capitalization obtained from the CSMAR database, scaled in units of RMB 10 billion (10^{10} RMB, i.e., dividing raw RMB market capitalization by 10^{10}; in our dataset, this scaled series is denoted EMV, whereas the log-transformed market capitalization series used as an alternative valuation measure in Section 4.3.1 is denoted EMV0). Market capitalization directly reflects capital-market valuation of the firm's listed equity while avoiding the missing-data attrition associated with replacement cost estimates in Tobin's Q.

3.2.2. Digital Transformation, ESG Performance, and Their Synergy

Corporate digital transformation (DIG) is measured via textual analysis of firms' annual reports across five technology domains, including artificial intelligence, big data, cloud computing, blockchain, and digital technology applications, following Wu et al. [11]. Specifically, the frequencies of keywords across these five domains are aggregated at the firm–year level and log-transformed to obtain DIG, while ESG performance (ESG) is measured by the natural logarithm of the Sino-Securities (Huazheng) comprehensive ESG score. In the baseline regressions in Section 4.2, DIG and ESG are first examined separately as standalone component benchmarks, whereas our focal explanatory variable (DESG) measures their synergistic coupling coordination.

To capture both the reciprocal interaction and the coordinated development of digital transformation and ESG performance, we construct the digital–ESG synergy index ($DESG_{it}$) using the coupling coordination degree (CCD) model following Sun et al. [10]. Let $U_{D,it}$ and $U_{E,it}$ denote firm i's digital transformation and ESG performance subsystem levels in year t. Equation (1) specifies the coupling degree C_{it}, which measures the interaction intensity and relative balance between the two subsystems:

$$C_{it} = 2 \times \left[\frac{U_{D,it} \times U_{E,it}}{\left(U_{D,it} + U_{E,it}\right)^2} \right]^{1/2} \quad (1)$$

Equation (2) defines the comprehensive coordination development index T_{it}, where α and β denote the relative weights of the digital transformation and ESG subsystems (set to $\alpha = 0.5$ and $\beta = 0.5$ as both strategies are equally vital to corporate sustainability). Equation (3) then combines the coupling degree C_{it} and the comprehensive development

index T_{it} to obtain the coupling coordination degree DESG_{it}, where higher values indicate stronger coupling coordination synergy between a firm's digital transformation and ESG governance:

$$T_{it} = \alpha U_{\mathrm{D},it} + \beta U_{\mathrm{E},it} \quad (2)$$

$$\mathrm{DESG}_{it} = \sqrt{C_{it} \times T_{it}} \quad (3)$$

3.2.3. Mechanism Variables

Consistent with our three-stage value creation framework, the mechanism analysis examines five organizational outcomes across three domains. First, internal conversion capacities are measured by three dynamic capabilities following Mo et al. [53]: absorptive capability (XSA), defined as the ratio of annual R&D expenditure to operating revenue; innovation capability (INA), constructed as the sum of standardized R&D intensity and standardized log-transformed invention patent applications; and adaptive capability (SA), measured by the negative coefficient of variation across R&D, capital, and advertising expenditures (so that higher values reflect more balanced and flexible resource deployment). Second, operational green transformation (SZ) is measured as the natural logarithm of one plus the firm's green transformation textual index, which aggregates 113 environmental keywords across five domains (environmental advocacy, strategic vision, green technological innovation, pollution abatement, and environmental monitoring) [54,55]. Third, external stakeholder valuation is captured by corporate reputation (SY), measured as the natural logarithm of the composite corporate reputation score constructed from 12 stakeholder evaluation indicators following Guan and Zhang [56].

3.2.4. Moderating Variables

The moderation analysis evaluates three internal implementation conditions and two external information-attention conditions, all measured as continuous variables. Among the internal moderators, entrepreneurial spirit (ESP) is an entropy-weighted composite index combining patent applications, fixed assets per employee, operating revenue per employee, intangible assets per employee, and the proportion of independent directors on the board, capturing management's commitment to innovation-oriented resource allocation and independent oversight [42,52]. Green governance recognition (GGR) measures top management's environmental attention as the ratio of executive green-cognition keyword occurrences (covering green competitive advantage, corporate social responsibility, and external environmental pressure) to total annual-report words (multiplied by 100). New quality productive forces (NPRO) is constructed following the 12-indicator entropy-weighted framework of Zhang et al. [45] (scaled by dividing by 100), encompassing high-skilled human capital (postgraduate employee share, R&D personnel share, executive digital background, CEO functional breadth), intelligent and green innovation outputs (robot penetration, total and green patents), and productive asset structure (fixed-to-total assets, digital-to-intangible assets, intelligence-related keyword frequency, and environmental performance).

Among the external moderators, media coverage (Media) is defined as the natural logarithm of one plus the annual number of financial news headlines mentioning the firm, and analyst attention (ANALY) is defined as the natural logarithm of one plus the number of securities analysts tracking the firm during the year.

Annual reports are obtained from CNINFO, patent records are obtained from Tonghuashun, and financial, corporate governance, media, and analyst coverage data are obtained from the CSMAR and Wind databases.

3.2.5. Control Variables

The regression models control for nine firm- and industry-level characteristics: firm age (FirmAge), management ownership (Mshare), board size (Board), operating cash flow (CashFlow), financial leverage (Lev), ownership concentration (Top3), CEO–chair duality (Dual), revenue growth (Growth), and industry concentration (HHI). Specifically, FirmAge is the natural logarithm of the current year minus the firm's establishment year plus one [57]; Mshare is the ratio of management-held shares to total shares outstanding [24]; Board is the natural logarithm of the total number of board directors [58]; CashFlow is net operating cash flow divided by total assets [59]; Lev is year-end total liabilities divided by total assets [58]; Top3 is the combined shareholding ratio of the top three shareholders [58]; Dual equals one when the board chair and CEO are the same person and zero otherwise (with occasional missing entries filled using the within-firm mean) [58]; Growth is the annual rate of operating revenue growth [59]; and HHI is the Herfindahl–Hirschman Index of industry revenue concentration [60].

Specifically, the HHI is computed at the industry–year level as the sum of squared firm revenue shares within each China Securities Regulatory Commission (CSRC) 2012 two-digit industry category (covering 79 industry categories and 923 industry–year cells across the sample period). Higher HHI values indicate greater industry concentration and weaker product-market competition.

3.3. Empirical Model Specifications

First, Equation (4) tests H1 by regressing enterprise market value on DESG and the controls defined in Table 1. The subscripts i and t denote firm and year, respectively; firm fixed effects absorb time-invariant firm characteristics, year fixed effects absorb common macroeconomic and institutional shocks, and the final term is the regression error. The coefficient on DESG is the parameter of interest and represents the within-firm association between DESG and EMV conditional on the included covariates and fixed effects:

$$\mathrm{EMV}_{it} = \alpha_0 + \alpha_1 \mathrm{DESG}_{it} + \alpha_2 \mathrm{Controls}_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

Table 1. Variable definitions.

Variable Type	Variable Name	Symbol	Definition
Dependent Variable	Enterprise Market Value	EMV	Annual A-share market capitalization from the CSMAR database, scaled in units of RMB 10 billion (10^{10} RMB)
Explanatory Variables	Digital Transformation	DIG	Log-transformed frequency of digital transformation keywords, following Wu et al. [11]
	ESG Performance	ESG	Natural logarithm of the Sino-Securities (Huazheng) comprehensive ESG score: $\ln(S_{it})$
	Digital–ESG Synergy	DESG	Coupling coordination degree (CCD) measuring the synergy between digital transformation and ESG performance, computed as $\sqrt{(C_{it} \times T_{it})}$ in Equations (1)–(3)

Table 1. *Cont.*

Variable Type	Variable Name	Symbol	Definition
Mechanism Variables	Dynamic Capabilities	XSA; INA; SA	Absorptive capability (XSA: R&D expenditure/operating revenue), innovation capability (INA: standardized R&D intensity + standardized ln(1 + invention patents)), and adaptive capability (SA: negative coefficient of variation of R&D, capital, and advertising outlays), following Mo et al. [53]
	Green Transformation	SZ	Natural logarithm of one plus the annual-report green transformation index across 113 environmental keywords in five domains, following Xie and Zhu [54] and Wan et al. [55]
	Corporate Reputation	SY	Natural logarithm of the 12-indicator composite corporate reputation score, following Guan and Zhang [56]
Moderating Variables	Media Coverage	Media	Natural logarithm of one plus the annual number of news headlines mentioning the firm
	Analyst Attention	ANALY	Natural logarithm of one plus the annual number of securities analysts tracking the firm
	New Quality Productive Forces	NPRO	Continuous 12-indicator entropy-weighted composite index of high-skilled labor, intelligent/green innovation, and digital/productive assets (scaled ÷ 100), following Zhang et al. [45]
	Green Governance Recognition	GGR	Continuous ratio of executive green-cognition keyword frequency to total annual-report words (×100)
	Entrepreneurial Spirit	ESP	Continuous entropy-weighted composite index of patent applications, fixed assets per employee, revenue per employee, intangible assets per employee, and independent director ratio
Control Variables	Firm Age	FirmAge	Natural logarithm of (current year − establishment year + 1)
	Management Ownership	Mshare	Management-held shares divided by total shares outstanding
	Board Size	Board	Natural logarithm of total board members
	Cash Flow	CashFlow	Net cash flow from operating activities divided by total assets
	Asset–liability ratio	Lev	Total liabilities at year-end divided by total assets at year-end

Table 1. *Cont.*

Variable Type	Variable Name	Symbol	Definition
	Ownership Concentration	Top3	Combined shares held by the top three shareholders divided by total shares outstanding
	CEO–Chair Duality	Dual	Indicator equal to 1 if the board chair and CEO are the same person, and 0 otherwise
	Firm Growth	Growth	(Current-year operating revenue/prior-year operating revenue) − 1
	Market Competition	HHI	Herfindahl–Hirschman Index: sum of squared firm revenue shares within each CSRC 2012 two-digit industry–year group (79 categories)

Notes: Table 1 summarizes the operational definitions and data sources of all variables used in the empirical analysis. DESG is the coupling coordination degree defined in Equations (1)–(3) in Section 3.2.2.

Second, following Jiang [49], Equation (5) evaluates H2a1–H2a3, H2b, and H2c using separate regressions in which each mechanism variable is regressed on DESG and the baseline controls. The coefficient on DESG tests whether DESG is associated with the relevant mechanism variable in the theoretically predicted direction:

$$\text{Mechanism}_{it} = \beta_0 + \beta_1 \text{DESG}_{it} + \beta_2 \text{Controls}_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (5)$$

Third, Equation (6) evaluates Hypotheses H3a–H3e by interacting DESG separately with each internal or external moderator (Moder_{it}). The specification includes DESG, the moderator, their multiplicative interaction ($\text{DESG}_{it} \times \text{Moder}_{it}$), the baseline control vector, and firm and year fixed effects. Under Equation (6), the conditional marginal slope of EMV with respect to DESG at a given moderator value m is $\partial \text{EMV}_{it}/\partial \text{DESG}_{it} = \varphi_1 + \varphi_3 m$. A positive interaction coefficient ($\varphi_3 > 0$) indicates that the marginal DESG slope shifts upward as the moderator increases; to assess whether the conditional slope is positive, negative, or statistically indistinguishable from zero across the observed support of each moderator, we evaluate $\varphi_1 + \varphi_3 m$ and its 95% confidence interval at the 25th, 50th, and 75th percentiles of each moderator (reported in Section 4.5, Table A4, and Figure A2):

$$\begin{aligned} \text{EMV}_{it} = \varphi_0 + \varphi_1 \text{DESG}_{it} + \varphi_2 \text{Moder}_{it} + \varphi_3 (\text{DESG}_{it} \times \text{Moder}_{it}) \\ + \varphi_4 \text{Controls}_{it} + \mu_i + \lambda_t + \varepsilon_{it} \end{aligned} \quad (6)$$

4. Empirical Results

4.1. Descriptive Statistics and Correlations

Table 2 summarizes the distribution of the variables used in the empirical analysis. EMV averages 1.941 (SD = 3.914) and ranges from 0.069 to 39.821, indicating wide dispersion in enterprise market value across observations. DESG averages 3.684 (SD = 2.888) and ranges from 0 to 14.368. DIG also varies substantially (mean = 1.602; SD = 1.452), whereas the logged ESG measure is more concentrated (mean = 4.287; SD = 0.077). These pooled distributions establish sample-level variation; the fixed-effects analysis below evaluates the relationship using within-firm changes.

Table 2. Descriptive statistics and correlations with EMV.

Variable	Corr. with EMV	*N*	Mean	Std. Dev.	Min	Max
EMV	1.000	26,486	1.941	3.914	0.069	39.821
ESG	0.227 ***	26,486	4.287	0.077	3.728	4.585
DIG	0.079 ***	26,486	1.602	1.452	0.000	6.306
DESG	0.091 ***	26,486	3.684	2.888	0.000	14.368
FirmAge	0.090 ***	26,486	2.989	0.315	1.099	4.290
Mshare	−0.156 ***	26,486	0.115	0.176	0.000	0.704
Board	0.156 ***	26,486	2.122	0.195	1.609	2.708
CashFlow	0.131 ***	26,486	0.047	0.064	−0.202	0.267
Lev	0.213 ***	26,486	0.446	0.189	0.032	0.910
Top3	0.194 ***	26,486	0.462	0.152	0.146	0.869
Dual	−0.052 ***	26,486	0.280	0.447	0.000	1.000
Growth	0.025 ***	26,486	0.142	0.392	−0.673	5.076
HHI	0.061 ***	26,486	0.082	0.090	0.013	0.797

Notes: Table 2 reports descriptive statistics and bivariate correlations with enterprise market value (EMV) for the Chinese A-share panel during 2011–2024 (N = 26,486). The second column reports pairwise correlations with EMV. *** $p < 0.01$.

Table 2 also reports bivariate correlations with EMV. EMV is positively correlated with the logged ESG measure (r = 0.227), DIG (r = 0.079), and measured DESG (r = 0.091), all at $p < 0.01$; the absolute correlations between the remaining firm characteristics and EMV do not exceed 0.213. These pooled correlations are descriptive: they neither establish causality nor, by themselves, demonstrate strategic integration. They nevertheless motivate the multivariate specifications with firm-level covariates and fixed effects.

4.2. Baseline Results

Table 3 reports the baseline two-way fixed-effects estimates of how digital transformation, ESG performance, and their synergy (DESG) enhance enterprise market value (EMV). Columns (1)–(4) first establish standalone component benchmarks: the coefficients on digital transformation (DIG) are 0.147 ($t = 8.05$, $p < 0.01$) without control variables and 0.146 ($t = 8.06$, $p < 0.01$) with the baseline controls, while the coefficients on ESG performance (ESG) are 3.233 ($t = 15.82$, $p < 0.01$) and 3.290 ($t = 15.96$, $p < 0.01$), respectively. Columns (5) and (6) then report our focal estimates for digital transformation and ESG synergy (DESG). The coefficient on DESG is 0.056 ($t = 7.00$, $p < 0.01$) without controls and 0.055 ($t = 6.88$, $p < 0.01$) in the fully specified model controlling for firm characteristics and firm and year fixed effects, supporting Hypothesis H1 that digital transformation and ESG synergy significantly enhances enterprise market value.

Consistent with the empirical framework of Sun et al. [10] and Liu et al. [61], presenting the standalone subsystem benchmarks (DIG and ESG) alongside the coupling coordination synergy index (DESG) demonstrates that both individual strategies and their synergistic coupling coordination contribute positively to enterprise market value.

In terms of economic magnitude within the 26,486-observation baseline sample (where DESG has a pooled standard deviation of 2.888 and a within-firm demeaned standard deviation of 1.616, and EMV has a sample mean of 1.941), a one-standard-deviation increase in DESG corresponds to a 0.158-unit increase in EMV (8.16% of the sample mean), while a one-within-firm-standard-deviation increase corresponds to a 0.089-unit increase in EMV (4.57% of the sample mean). In Column (6), overall R-squared is 0.841 and within R-squared after absorbing firm and year fixed effects is 0.0132.

Table 3. Baseline two-way fixed-effects estimates of enterprise market value.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	EMV	EMV	EMV	EMV	EMV	EMV
DIG	0.147 ***	0.146 ***				
	(8.05)	(8.06)				
ESG			3.233 ***	3.290 ***		
			(15.82)	(15.96)		
DESG					0.056 ***	0.055 ***
					(7.00)	(6.88)
FirmAge		1.471 ***		1.397 ***		1.460 ***
		(4.27)		(4.09)		(4.24)
Mshare		1.340 ***		1.217 ***		1.336 ***
		(10.80)		(9.87)		(10.75)
Board		0.231 **		0.277 **		0.245 **
		(2.10)		(2.54)		(2.23)
CashFlow		0.913 ***		0.941 ***		0.909 ***
		(4.25)		(4.41)		(4.23)
Lev		0.632 ***		0.841 ***		0.648 ***
		(6.64)		(8.81)		(6.80)
Top3		1.314 ***		1.203 ***		1.280 ***
		(5.88)		(5.40)		(5.73)
Dual		0.021		0.025		0.021
		(0.66)		(0.78)		(0.65)
Growth		0.155 ***		0.172 ***		0.156 ***
		(4.98)		(5.58)		(5.04)
HHI		−0.105		−0.218		−0.120
		(−0.37)		(−0.78)		(−0.43)
Constant	1.710 ***	−4.279 ***	−11.914 ***	−18.049 ***	1.738 ***	−4.233 ***
	(54.66)	(−3.95)	(−13.59)	(−12.65)	(54.89)	(−3.91)
Observations	26,486	26,486	26,486	26,486	26,486	26,486
R-squared	0.839	0.841	0.841	0.843	0.839	0.841
Controls	NO	YES	NO	YES	NO	YES
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Notes: Columns (1)–(6) report baseline two-way fixed-effects estimates for digital transformation (DIG), ESG performance (ESG), and digital transformation–ESG synergy (DESG). T-statistics in parentheses are based on heteroskedasticity-robust standard errors. ** $p < 0.05$; *** $p < 0.01$.

4.3. Robustness and Endogeneity Checks

4.3.1. Alternative Measures, Samples, and Standard Errors

Table 4 first tests whether the baseline finding holds under alternative enterprise market value and synergy specifications. In Column (1), replacing the baseline EMV measure with the alternative enterprise market value measure EMV0 yields a positive and significant DESG coefficient of 0.012 ($t = 2.63$, $p < 0.01$). In Column (2), estimating a multiplicative interaction model (DIG × ESG) alongside its constitutive main effects (DIG and ESG) yields a positive interaction coefficient of 1.539 ($t = 10.83$, $p < 0.01$), providing complementary evidence that digital transformation and ESG performance positively reinforce one another in enhancing enterprise market value.

Consistent with Lan and Zhou [62], this multiplicative interaction specification complements our baseline coupling coordination model by confirming that digital transformation and ESG performance mutually reinforce each other in enhancing enterprise market value.

Table 4. Robustness checks: alternative measures, samples, and inference.

	(1)	(2)	(3)	(4)	(5)
	Alt. EMV measure	Component interaction	Excl. municipalities	Excl. 2020–2024	Driscoll–Kraay SE
VARIABLES	EMV0	EMV	EMV	EMV	EMV
DESG	0.012 ***		0.059 ***	0.044 ***	0.055 ***
	(2.63)		(7.51)	(5.30)	(4.84)
DIG		−6.456 ***			
		(−10.74)			
ESG		0.647 **			
		(2.33)			
DIG × ESG		1.539 ***			
		(10.83)			
Constant	19.822 ***	−6.648 ***	−1.924 **	−2.047	−3.829 ***
	(97.72)	(−4.10)	(−2.05)	(−1.61)	(−3.69)
Observations	26,486	26,486	21,716	17,684	26,486
R-squared	0.899	0.844	0.807	0.854	
Controls	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Number of groups					3084

Notes: Column (1) uses the alternative enterprise market value measure EMV0; Columns (2)–(5) use EMV. Column (2) estimates the multiplicative interaction DIG × ESG controlling for DIG and ESG main effects; Column (3) excludes firms located in the four centrally administered municipalities; Column (4) excludes the 2020–2024 period; and Column (5) reports Driscoll–Kraay standard errors (Bartlett kernel, bandwidth lag 2, $N = 26{,}486$; bandwidth lags 1, 3, and 4 likewise yield $p < 0.001$). T-statistics are in parentheses. ** $p < 0.05$; *** $p < 0.01$.

As an alternative ESG rating check, we reconstruct the digital–ESG synergy index (denoted D1) by replacing the Sino-Securities (Huazheng) ESG score with the Bloomberg overall ESG score. Controlling for the nine baseline covariates and firm and year fixed effects across the 9352 firm–year observations (1103 firms) with Bloomberg coverage, the coefficient on D1 is 0.334 (robust SE = 0.038, $t = 8.80$, $p < 0.001$, 95% CI [0.260, 0.409]; overall R-squared = 0.833, within R-squared = 0.034), confirming that the positive effect of digital transformation and ESG synergy on enterprise market value holds under an independent international ESG rating provider.

Table 4 next examines sample composition and statistical inference. The DESG coefficient remains positive and significant at the 1% level when firms located in the four centrally administered municipalities are excluded (0.059, $t = 7.51$), when observations from 2020–2024 are excluded (0.044, $t = 5.30$), and when Driscoll–Kraay standard errors are applied (0.055, $t = 4.84$). These checks confirm that the positive effect of digital transformation and ESG synergy on enterprise market value is robust across regional subsamples, sample windows, and cross-sectionally dependent error structures.

4.3.2. Propensity Score Matching and Instrumental Variables

Table 5, Column (1), reports propensity score matching (PSM) estimates to address observable selection differences. Firms with DESG at or above the annual sample median are assigned to the high-DESG group and matched to comparison firms via 1:1 nearest-neighbor logit matching with replacement and a 0.05 caliper across the nine baseline covariates. Re-estimating the two-way fixed-effects model on the matched common support sample ($N = 13{,}544$; 6679 treated and 6865 control observations) yields a positive and significant DESG coefficient of 0.056 (robust SE = 0.012, $t = 4.53$, $p < 0.01$, 95% CI [0.032, 0.081]).

Table 5. Propensity score matching and instrumental variable estimates.

	(1)	(2)	(3)	(4)	(5)
	PSM	Bartik IV: second stage	Bartik IV: first stage	Peer-mean IV: second stage	Peer-mean IV: first stage
VARIABLES	EMV	EMV	DESG	EMV	DESG
DESG	0.056 ***	0.192 ***		0.202 ***	
	(4.53)	(5.16)		(6.10)	
Bartik DESG IV			0.467 ***		
			(31.51)		
Peer-mean DESG IV					0.583 ***
					(26.88)
First-stage F		992.883 [$p < 0.001$]	992.883 [$p < 0.001$]	722.385 [$p < 0.001$]	722.385 [$p < 0.001$]
Kleibergen–Paap rk LM		855.486 [$p < 0.001$]	855.486 [$p < 0.001$]	588.893 [$p < 0.001$]	588.893 [$p < 0.001$]
Kleibergen–Paap rk Wald F		992.883	992.883	722.385	722.385
Stock–Yogo critical value		16.38	16.38	16.38	16.38
Observations	13,544	21,993	21,993	26,471	26,471
R-squared	0.863	0.115		0.125	
Controls	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES
Year FE	YES	NO	NO	NO	NO

Notes: Column (1) reports the two-way fixed-effects estimate on the 1:1 nearest-neighbor propensity score-matched sample. Columns (2)–(3) and Columns (4)–(5) report the second- and first-stage 2SLS estimates for the Bartik-style and leave-one-out industry–year peer-mean instruments, respectively. In single-instrument specifications, the excluded-instrument F-statistic equals the squared first-stage t-statistic (992.883 and 722.385). Heteroskedasticity-robust t-statistics are in parentheses; *p*-values for underidentification (Kleibergen–Paap rk LM) and first-stage F tests are in brackets. *** $p < 0.01$.

Covariate balance diagnostics (reported in Appendix A Table A3 and Figure A1) confirm that matching reduces the mean absolute standardized bias across the nine covariates from 8.71% to 1.40%, lowers Rubin's B from 36.94 to 5.77, and brings Rubin's R from 1.38 to 1.01.

Columns (2)–(5) of Table 5 report two-stage least squares (2SLS) instrumental variable estimations controlling for firm fixed effects and the nine baseline covariates. The first instrument (Bartik DESG IV) multiplies lagged firm DESG by the annual change in the national sample mean of DESG ($N = 21{,}993$), and the second instrument (Peer-mean DESG IV) is the leave-one-out industry–year mean of DESG across 18 CSRC single-letter industry sectors ($N = 26{,}471$). First-stage regressions confirm strong instrument relevance, with first-stage coefficients of 0.467 ($t = 31.51$, Kleibergen–Paap rk Wald F = 992.883) and 0.583 ($t = 26.88$, Kleibergen–Paap rk Wald F = 722.385), respectively. The second-stage DESG coefficients are 0.192 ($t = 5.16$, $p < 0.01$) and 0.202 ($t = 6.10$, $p < 0.01$).

As documented in Appendix A Table A2, because the aggregate shift in the Bartik-style instrument and the sector–year peer mean primarily capture macroeconomic and industry-wide time trends, adding explicit year fixed effects absorbs much of this temporal variation and renders the second-stage IV point estimates statistically imprecise (0.012, 95% CI [−0.058, 0.083] for the Bartik instrument; −0.083, 95% CI [−0.192, 0.026] for the peer-mean instrument). Accordingly, we interpret our empirical findings as robust conditional panel associations rather than definitive causal effects.

4.4. Mechanism Analysis

Table 6 examines the value formation mechanisms through which digital transformation and ESG synergy (DESG) enhances enterprise market value. In Columns (1)–(3),

DESG is positively and significantly associated with absorptive capability (XSA: coefficient = 0.001, $t = 5.87$, $p < 0.01$), innovation capability (INA: coefficient = 0.010, $t = 5.18$, $p < 0.01$), and adaptive capability (SA: coefficient = 0.003, $t = 3.36$, $p < 0.01$). Combined with established evidence on the role of dynamic capabilities in enhancing enterprise market value [15,30,31], these results support Hypotheses H2a1, H2a2, and H2a3.

Table 6. Mechanism variable test estimates.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	XSA	INA	SA	SZ	SY
DESG	0.001 ***	0.010 ***	0.003 ***	0.003 ***	0.021 ***
	(5.87)	(5.18)	(3.36)	(4.97)	(12.43)
Constant	−0.056 ***	1.351 ***	−1.415 ***	1.200 ***	0.547 ***
	(−4.76)	(6.62)	(−15.59)	(19.73)	(3.27)
Observations	26,486	26,486	26,475	26,486	26,377
R-squared	0.806	0.419	0.689	0.654	0.794
Controls	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

Notes: Columns (1)–(3) test dynamic capabilities (H2a1: absorptive capability XSA; H2a2: innovation capability INA; H2a3: adaptive capability SA), Column (4) tests green transformation (H2b: SZ), and Column (5) tests corporate reputation (H2c: SY). All models include the nine baseline controls in Table 1 and firm and year fixed effects. Heteroskedasticity-robust t-statistics are in parentheses. *** $p < 0.01$.

In Columns (4) and (5), DESG is also positively and significantly associated with operational green transformation (SZ: coefficient = 0.003, $t = 4.97$, $p < 0.01$) and external corporate reputation (SY: coefficient = 0.021, $t = 12.43$, $p < 0.01$). Together with prior evidence linking green transformation and corporate reputation to enterprise market value [22,34,38,39], these findings support Hypotheses H2b and H2c.

Consistent with Jiang [49], these regressions establish significant positive first-link associations between DESG and each proposed mechanism construct; all five estimates remain statistically significant at $p < 0.001$ after Holm step-down multiplicity adjustment (Appendix A Table A5).

4.5. Moderation Analysis

Table 7 reports the moderation estimates for Equation (6). For the external information-attention moderators in Columns (1) and (2), the interaction coefficient on DESG × Media is 0.049 ($t = 8.72$, $p < 0.01$) and that on DESG × ANALY is 0.104 ($t = 17.91$, $p < 0.01$). In both specifications, the positive and statistically significant interaction coefficient confirms that the marginal slope of EMV with respect to DESG shifts upward as media coverage or analyst coverage increases, consistent with H3d and H3e.

Columns (3)–(5) report the internal implementation moderators. The interaction coefficients are 0.012 for DESG × ESP ($t = 9.59$, $p < 0.01$), 0.025 for DESG × GGR ($t = 4.14$, $p < 0.01$), and 1.073 for DESG × NPRO ($t = 10.23$, $p < 0.01$), supporting the positive moderation gradients hypothesized in H3a–H3c. Because the moderators enter Table 7 in uncentered form, the negative main coefficients on DESG in Columns (1)–(3) and (5) reflect the extrapolated slope at a moderator value of zero (which lies outside or at the lower boundary of the sample distribution for variables such as ESP, whose mean is 32.66). When the five moderators are mean-centered so that the main DESG coefficient measures the marginal effect at each moderator's sample mean, the main DESG coefficient is positive and statistically significant at the 1% level across all five columns, namely, 0.053 ($t = 6.72$) for Media, 0.037 ($t = 4.77$) for ANALY, 0.045 ($t = 5.86$) for ESP, 0.053 ($t = 6.66$)

for GGR, and 0.044 ($t = 5.42$) for NPRO, while all five interaction coefficients and t-statistics remain identical.

Table 7. Moderating variable estimates.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	EMV	EMV	EMV	EMV	EMV
DESG	−0.163 ***	−0.105 ***	−0.335 ***	0.025 **	−0.094 ***
	(−7.38)	(−14.91)	(−9.08)	(2.42)	(−7.36)
Media	0.041 *				
	(1.84)				
DESG × Media	0.049 ***				
	(8.72)				
ANALY		0.050 **			
		(1.99)			
DESG × ANALY		0.104 ***			
		(17.91)			
ESP			−0.005		
			(−0.76)		
DESG × ESP			0.012 ***		
			(9.59)		
GGR				0.000	
				(0.00)	
DESG × GGR				0.025 ***	
				(4.14)	
NPRO					−0.990 **
					(−2.31)
DESG × NPRO					1.073 ***
					(10.23)
Constant	−4.595 ***	−3.618 ***	−3.990 ***	−4.249 ***	−3.509 ***
	(−4.21)	(−3.38)	(−3.57)	(−3.92)	(−3.22)
Observations	26,486	26,486	26,486	26,486	26,486
R-squared	0.843	0.851	0.844	0.841	0.844
Controls	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

Notes: Columns (1)–(5) estimate Equation (6) for Media, analyst attention (ANALY), entrepreneurial spirit (ESP), green governance recognition (GGR), and new quality productive forces (NPRO), respectively, with the nine baseline controls and firm and year fixed effects. In uncentered form, the main DESG coefficient reflects the slope at moderator zero; when moderators are mean-centered, the main DESG coefficients at the sample mean are 0.053 *** (6.72), 0.037 *** (4.77), 0.045 *** (5.86), 0.053 *** (6.66), and 0.044 *** (5.42) in Columns (1)–(5), respectively. Conditional slopes at P25, P50, and P75 are reported in Appendix A Table A4 and Figure A2. Heteroskedasticity-robust t-statistics are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

To provide a precise substantive interpretation across the observed moderator distributions, we compute the conditional marginal slope ($\varphi_1 + \varphi_3$ m) and its 95% confidence interval at the 25th (P25), 50th (P50), and 75th (P75) percentiles of each moderator (reported in Appendix A Table A4 and plotted in Stata Figure A2). These conditional slopes reveal two distinct moderation regimes. First, Media and GGR act as uniform amplifiers: the conditional DESG slope is positive and statistically significant across all three quartiles—rising from 0.028 ($p < 0.001$) at P25 to 0.059 at P50 and 0.086 at P75 for Media, and from 0.025 ($p = 0.015$) at P25 to 0.053 at P50 and 0.071 at P75 for GGR. Second, ANALY, NPRO, and ESP act as threshold (enabling) conditions: at the 25th percentile, the conditional DESG slope is negative and significant for ANALY (−0.105, $p < 0.001$, 95% CI [−0.119, −0.091]) and for NPRO (−0.018, $p = 0.028$, 95% CI [−0.033, −0.002]), and statistically

indistinguishable from zero for ESP (−0.009, $p = 0.215$, 95% CI [−0.023, 0.005]). Once these moderators reach their sample medians (P50) and upper quartiles (P75), all three conditional DESG slopes become positive and highly significant ($p < 0.001$): 0.039 (P50) and 0.144 (P75) for ANALY; 0.037 (P50) and 0.081 (P75) for NPRO; and 0.041 (P50) and 0.091 (P75) for ESP. Economically, this threshold pattern indicates that when a firm lacks basic productive infrastructure (low NPRO), entrepreneurial risk-taking (low ESP), or external analyst coverage (low ANALY), pursuing digital and ESG initiatives simultaneously can impose net adjustment costs or face capital-market skepticism; positive valuation returns emerge only when internal implementation foundations and external professional scrutiny surpass a critical threshold.

4.6. Heterogeneity Analysis

4.6.1. Geographic Heterogeneity

Table 8 documents regional variation in the effect of digital transformation and ESG synergy (DESG) on enterprise market value (EMV). DESG is positively and significantly associated with EMV in eastern China (coefficient = 0.061, $t = 6.08$, $p < 0.01$) and central China (coefficient = 0.083, $t = 6.56$, $p < 0.01$), whereas the coefficient in western China is statistically indistinguishable from zero (coefficient = −0.006, $t = -0.26$). The Chow test confirms significant structural heterogeneity across regions ($p < 0.001$), reflecting stronger institutional, digital, and capital-market foundations in eastern and central China.

Table 8. Geographic heterogeneity estimates across Chinese regions.

	(1)	(2)	(3)
	Eastern Region	Central Region	Western Region
VARIABLES	EMV	EMV	EMV
DESG	0.061 ***	0.083 ***	−0.006
	(6.08)	(6.56)	(−0.26)
Constant	−7.289 ***	0.576	7.360 ***
	(−5.10)	(0.45)	(3.50)
Chow Test	7.93	7.93	7.93
Coefficient-difference *p*-value	<0.001	<0.001	<0.001
Observations	18,428	4452	3592
R-squared	0.858	0.799	0.755
Controls	YES	YES	YES
Firm FE	YES	YES	YES
Year FE	YES	YES	YES

Notes: Columns (1)–(3) report subgroup estimates for eastern, central, and western China, respectively. All models include the nine baseline controls in Table 1 and firm and year fixed effects. Heteroskedasticity-robust t-statistics are in parentheses. *** $p < 0.01$.

4.6.2. Industry Heterogeneity

Table 9 first compares firms in non-high-technology and high-technology industries. The DESG coefficient is positive in both groups—0.028 for non-high-technology firms ($t = 1.94$, $p < 0.10$) and 0.071 for high-technology firms ($t = 7.35$, $p < 0.01$)—and the Chow test confirms significant structural heterogeneity between the two technological groups ($p = 0.015$), indicating that high-technology firms more effectively convert digital–ESG synergy into enterprise market value.

Columns (3) and (4) of Table 9 compare non-heavy-pollution and heavy-pollution industries. The DESG coefficients are positive and significant at the 1% level in both non-heavy-pollution industries (0.058, $t = 6.09$, $p < 0.01$) and heavy-pollution industries (0.042, $t = 2.73$, $p < 0.01$), while the Chow test does not reject structural stability across pollution

groups ($p = 0.250$), indicating that digital transformation and ESG synergy enhances enterprise market value across both industry categories.

Table 9. Heterogeneity estimates across technological and pollution industry categories.

	(1)	(2)	(3)	(4)
VARIABLES	Non-high-tech industry EMV	High-tech industry EMV	Non-heavy-pollution industry EMV	Heavy-pollution industry EMV
DESG	0.028 *	0.071 ***	0.058 ***	0.042 ***
	(1.94)	(7.35)	(6.09)	(2.73)
Constant	−6.770 ***	−3.389 ***	−3.101 ***	−7.497 ***
	(−2.62)	(−2.97)	(−2.58)	(−2.62)
Chow Test	1.53	1.53	1.39	1.39
Coefficient-difference *p*-value	0.015	0.015	0.250	0.250
Observations	9386	17,016	20,149	6288
R-squared	0.862	0.835	0.835	0.871
Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Notes: Columns (1)–(2) compare non-high-technology and high-technology firms; Columns (3)–(4) compare non-heavy-pollution and heavy-pollution firms. All models include the nine baseline controls in Table 1 and firm and year fixed effects. Heteroskedasticity-robust t-statistics are in parentheses. * $p < 0.10$; *** $p < 0.01$.

4.6.3. Ownership and Firm Size Heterogeneity

Table 10 first examines ownership heterogeneity. Digital transformation and ESG synergy (DESG) is positively and significantly associated with enterprise market value under both ownership structures, with a coefficient of 0.044 for non-state-owned enterprises ($t = 5.00$, $p < 0.01$) and 0.077 for state-owned enterprises ($t = 4.89$, $p < 0.01$). The Chow test confirms significant structural heterogeneity ($p < 0.001$), with a larger valuation effect among state-owned enterprises.

Table 10. Heterogeneity estimates by state ownership and firm size.

	(1)	(2)	(3)	(4)
VARIABLES	Non-SOEs EMV	SOEs EMV	Small Firms EMV	Large Firms EMV
DESG	0.044 ***	0.077 ***	0.013 ***	0.084 ***
	(5.00)	(4.89)	(9.09)	(5.08)
Constant	−1.213	−11.243 ***	−0.643 ***	−11.315 ***
	(−1.09)	(−4.33)	(−4.20)	(−4.24)
Chow Test	18.60	18.60	179.70	179.70
Coefficient-difference *p*-value	<0.001	<0.001	<0.001	<0.001
Observations	16,786	9634	13,037	13,169
R-squared	0.790	0.875	0.684	0.846
Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Notes: Columns (1)–(2) compare non-state-owned enterprises (Non-SOEs) and state-owned enterprises (SOEs); Columns (3)–(4) compare small and large firms (split at the sample median of firm size). All models include the nine baseline controls in Table 1 and firm and year fixed effects. Heteroskedasticity-robust t-statistics are in parentheses. *** $p < 0.01$.

Columns (3) and (4) of Table 10 document firm size heterogeneity. The DESG coefficient is 0.013 for small firms ($t = 9.09$, $p < 0.01$) and 0.084 for large firms ($t = 5.08$, $p < 0.01$), and the Chow test confirms significant structural heterogeneity ($p < 0.001$), indicating that larger firms realize greater market value gains from digital–ESG synergy due to stronger resource scale and implementation capacity.

4.7. Further Analysis: Asymmetry

To examine distributional asymmetry across the enterprise market value distribution, Table 11 reports conditional quantile regressions (qreg) of enterprise market value (EMV) on digital transformation and ESG synergy (DESG), the nine baseline controls, and year fixed effects at the 0.10, 0.25, 0.50, 0.75, and 0.95 quantiles ($N = 26{,}486$). The estimated DESG coefficient is positive and statistically significant ($p < 0.01$) across all five quantiles, increasing monotonically from 0.012 ($t = 14.18$) at the 10th percentile to 0.038 ($t = 15.24$) at the median and 0.285 ($t = 4.91$) at the 95th percentile.

Table 11. Quantile regression estimates.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	$q = 0.10$	$q = 0.25$	$q = 0.50$	$q = 0.75$	$q = 0.95$
DESG	0.012 ***	0.022 ***	0.038 ***	0.076 ***	0.285 ***
	(14.18)	(16.72)	(15.24)	(10.87)	(4.91)
Constant	−0.311 ***	−0.718 ***	−1.688 ***	−3.695 ***	−9.366 ***
	(−8.02)	(−11.86)	(−14.62)	(−11.39)	(−3.49)
Observations	26,486	26,486	26,486	26,486	26,486
Controls	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	NO
Year FE	YES	YES	YES	YES	YES

Notes: Columns (1)–(5) report conditional quantile regressions at $q = 0.10$, 0.25, 0.50, 0.75, and 0.95, including the nine baseline controls and year fixed effects ($N = 26{,}486$). T-statistics are in parentheses. *** $p < 0.01$.

To formally test whether the DESG slope differs across quantiles on the 26,486-observation sample, a simultaneous quantile regression (sqreg with 100 bootstrap replications) strongly rejects the null hypothesis of equal DESG slopes across all five quantiles ($F = 144.00$, $p < 0.001$) as well as between the 10th and 95th percentiles ($F = 153.12$, $p < 0.001$), confirming that digital transformation and ESG synergy exerts a stronger value-enhancing effect among higher-valuation enterprises.

5. Discussion and Conclusions

Firms increasingly pursue digital transformation and ESG practices in parallel, yet concurrent investment does not guarantee that the two agendas function as a coherent value-creating system. Drawing on 26,486 firm–year observations of Chinese A-share listed companies from 2011 to 2024, this study investigates how coupling-based digital–ESG synergy (DESG) relates to enterprise market value across an integrated three-stage framework linking strategic resource configuration, internal organizational conversion, and external capital-market recognition.

5.1. Key Findings

In the baseline two-way fixed-effects specification controlling for firm characteristics and firm and year fixed effects, DESG is positively and significantly associated with enterprise market value (coefficient = 0.055, 95% CI [0.039, 0.070], $p < 0.001$). This positive

association holds across alternative valuation scaling (EMV0), Bloomberg ESG rating substitution (D1), municipality and post-2020 sample exclusions, Driscoll–Kraay inference, and propensity score matching.

The mechanism results clarify how DESG can contribute to enterprise market value. DESG positively predicts absorptive, innovation, and adaptive capabilities, documented green transformation engagement, and corporate reputation. These first-link estimates, together with established evidence that the five organizational outcomes are value relevant [15,22,30,31,34,38,39], support three plausible value formation pathways: stronger organizational conversion capacity, reported green engagement, and favorable stakeholder recognition. The analysis therefore supports H2a1–H2a3, H2b and H2c while preserving the Jiang [49] design: it estimates DESG-to-mechanism-variable relationships, whereas the mechanism-variable-to-EMV links are supported by the prior literature rather than separate mediation or indirect effect equations.

The moderation analysis reveals an important distinction between uniform amplification and threshold conditioning. While all five interaction terms are positive and significant ($p < 0.01$), conditional slope evaluations across quartiles (Table A4 and Figure A2) show that media coverage and green governance recognition positively amplify the DESG–EMV association across all quartiles, whereas analyst attention, new quality productive forces, and entrepreneurial spirit exhibit threshold effects: their conditional DESG slopes are negative (ANALY: −0.105; NPRO: −0.018) or statistically insignificant (ESP: −0.009) at the 25th percentile and turn significantly positive at the median and 75th percentile. This finding underscores that dual digital–ESG transformation is not unconditionally value-enhancing; without sufficient productive infrastructure, entrepreneurial leadership, and external analyst scrutiny, simultaneous digital and ESG investments can incur net adjustment costs before generating positive market returns.

The heterogeneity analysis further clarifies the contextual boundaries of digital transformation and ESG synergy in enhancing enterprise market value. The positive DESG–EMV association is significant in eastern and central China and more pronounced among high-technology firms, state-owned enterprises, and large firms, whereas pollution industry status does not produce a significant structural difference. Furthermore, conditional quantile regressions demonstrate that the value-enhancing effect of DESG increases monotonically across the enterprise market value distribution.

5.2. Comparison with the Prior Literature

Our findings extend the literature linking digital transformation and ESG to firm performance [11,12,14,16–19,23] by making their coupling coordination synergy the focal explanatory construct in explaining enterprise market value. Specifically, while Qi et al. [23] and Lan and Zhou [62] model conditional relationships using linear interaction terms (DIG × ESG), Dou and Jia [63] examine the synergistic empowerment of digital transformation and ESG on enterprise green innovation, and Sun et al. [10] and Liu et al. [61] apply coupling coordination models to corporate decarbonization and high-quality development, our study demonstrates that CCD-based digital–ESG synergy significantly enhances capital-market valuation through internal capability conversion, green transformation, and corporate reputation.

The mechanism evidence connects research streams that are commonly examined in isolation. Prior studies associate digital transformation with ESG improvement and sustainable development [6,7,9], dynamic capabilities with organizational performance and firm value [15,30,31], low-carbon transition with enterprise value [34], and corporate reputation with sustained performance and shareholder value [22,38,39]. The current findings place DESG upstream of outcomes in all three domains. They show a consistent

first-stage association between coordination and organizational conversion, reported green engagement, and external recognition, while existing evidence supplies the downstream value logic. This combination offers a coherent explanation of how coordinated strategic development can acquire market value relevance without claiming a mediation chain that is not estimated.

The boundary findings also refine prior accounts of digital transformation and ESG synergy. Research on digital sustainability and the twin transition recognizes both complementarity and implementation tensions [3,4]. Sun et al. [10] report stronger decarbonization effects among state-owned enterprises and firms in more developed regions. Consistent with those contextual patterns, our heterogeneity and moderation results [43–45,47,48] demonstrate that market value gains from digital transformation and ESG synergy depend on internal implementation capacity, external information intermediation, and regional and organizational foundations.

5.3. Theoretical Contributions and Boundary Refinements

First, this study advances resource complementarity research by shifting the focal construct from parallel standalone investments in digital transformation and ESG to their coupling coordination synergy. By applying the coupling coordination degree (CCD) model to capture both mutual interaction and coordinated development between the digital and ESG subsystems, we extend digital–ESG synergy research from environmental outcomes to capital-market valuation.

Second, the study develops a three-domain account of value formation. Dynamic capabilities represent the organizational capacity to absorb knowledge, innovate, and adapt; green transformation represents the operational implementation of sustainability objectives; and corporate reputation represents external evaluation of the firm's credibility. Integrating these domains connects resource complementarity, dynamic capabilities theory, and signaling theory within one explanatory structure. The empirical evidence establishes the first links from DESG to the five organizational outcomes, and the prior literature establishes why those outcomes matter for value. The contribution lies in identifying a coherent process architecture while keeping the theoretical claim aligned with the mechanism design.

Third, the study distinguishes internal implementation conditions from external information conditions and then locates the focal relationship across observable firm contexts. Entrepreneurial spirit, green governance recognition, and new quality productive forces characterize a firm's readiness to convert coordination into strategic action; media coverage and analyst attention characterize the information environment in which that action is evaluated. Regional, technological, ownership, and size differences further delimit the relationship, while the nonsignificant pollution status difference prevents an overly broad heterogeneity claim. This combined perspective qualifies digital–ESG synergy as a contingent source of market value and provides a framework for understanding why similar levels of measured coordination can have different valuation implications across firms.

5.4. Practical Implications

For corporate managers, the findings support managing digital transformation and ESG as a coordinated portfolio of strategic decisions. A practical starting point is to identify imbalances between the two subsystems and connect digital investments to material ESG objectives, data requirements, and operating processes. The mechanism results direct attention to the organizational outcomes that accompany stronger coordination: learning and reconfiguration capabilities, reported green transformation engagement, and credible reputation. The moderation results further indicate that entrepreneurial orientation, green governance recognition, and the productive and technological base condition the value

associated with DESG. Joint planning, shared performance objectives, and accountable implementation can help firms turn simultaneous investment into coherent development.

For investors, securities analysts, and policymakers, our threshold moderation results highlight that headline digital–ESG synergy scores must be evaluated in conjunction with a firm's underlying productive capacity (NPRO), managerial commitment (ESP and GGR), and external information transparency. Because firms in the lowest quartile of productive foundations or analyst coverage experience null or negative marginal valuation returns from DESG, capital-market participants and regulators should look beyond symbolic dual disclosures and focus on verifiable project-level integration.

For policymakers and industry organizations, the heterogeneous results favor differentiated capacity-building support over uniform policy assumptions. The weaker valuation effects in western China and among non-state-owned and smaller firms highlight contexts where digital infrastructure, green governance training, and financing support can ease implementation bottlenecks. Policy instruments should therefore target practical coordination constraints, improve the comparability and credibility of digital and ESG disclosures, and support firms in achieving substantive digital–ESG synergy.

5.5. Research Limitations and Future Directions

Several limitations suggest avenues for future research. First, our coupling coordination index (DESG) aggregates firm-level annual-report digital keyword frequencies and Sino-Securities ESG ratings under equal subsystem weights (0.5 and 0.5). Future research can explore industry-specific weighting schemes, multi-dimensional subsystem indicator systems, or project-level operational records to capture finer-grained organizational synergy.

Second, because observational panel data cannot completely rule out time-varying unobserved confounding, future studies can exploit quasi-experimental digital or ESG policy shocks and firm-level field data to strengthen causal identification.

Third, the mechanism analysis follows the first-link approach and therefore does not estimate mechanism-variable-to-EMV equations, temporal mediation, or indirect effects. This choice avoids treating potentially endogenous mechanism variables as if they were exogenous, but it also leaves the full sequence to future research. Studies with lagged organizational outcomes, primary process data, or exogenous changes in specific capabilities could test whether absorptive, innovation, and adaptive capabilities, green transformation, and corporate reputation precede subsequent changes in market value. These designs would provide more direct evidence on the timing and causal ordering of the proposed pathways.

Finally, the sample is confined to Chinese A-share listed companies during 2011–2024, where institutional and capital-market conditions may shape both strategic implementation and external valuation. Future research can extend this framework to cross-country comparative settings and unlisted enterprises to examine how digital transformation and ESG synergy enhances enterprise market value across diverse institutional environments.

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Appendix A. Supplementary Empirical Diagnostics

This appendix reports supplementary diagnostic tables and figures supporting the main text, including the annual-report length sensitivity check (Table A1), instrumental variable and dynamic panel diagnostics (Table A2), propensity score matching covariate balance and overlap (Table A3 and Figure A1), conditional DESG marginal slopes across moderator quartiles (Table A4 and Figure A2), and Holm step-down multiplicity adjustments (Table A5).

Table A1. Baseline interval and report length diagnostic.

Model	DESG	SE	95% CI	*p*
Original nine-control baseline	0.054839	0.007974	[0.039209, 0.070469]	<0.001
Baseline + log report length	0.028771	0.008180	[0.012738, 0.044803]	<0.001

Notes: Both models in Table A1 are estimated on $N = 26{,}486$ firm–year observations with the nine baseline controls and firm and year fixed effects. Row 2 adds the natural logarithm of total annual-report word count to control for document verbosity (DESG coefficient = 0.0288, robust SE = 0.0082, $p < 0.001$).

Table A2. Instrumental variable and same-sample OLS comparison.

IV Specification	*N*	IV DESG	IV 95% CI	OLS DESG	KP Wald F
bartik original	21,993	0.191968	[0.119112, 0.264824]	0.067090	992.883
peer original	26,471	0.202125	[0.137139, 0.267111]	0.071617	722.385
bartik yearFE	21,993	0.012219	[−0.058338, 0.082775]	0.050905	860.476
peer yearFE	26,471	−0.082989	[−0.192203, 0.026225]	0.054911	165.735

Notes: Table A2 compares the two-stage least squares (2SLS) estimates without and with explicit year fixed effects against same-sample OLS benchmarks. bartik original: first-stage coefficient 0.466908, $t = 31.510043$, t squared = 992.882822, excluded-instrument F = 992.882822; KP rk LM = 855.486 ($p < 0.001$). The same-sample OLS uses the same effects and controls. Hansen J is not applicable (one excluded instrument for one endogenous regressor). peer original: first-stage coefficient 0.582615, $t = 26.877215$, t squared = 722.384709, excluded-instrument F = 722.384709; KP rk LM = 588.893 ($p < 0.001$). The same-sample OLS uses the same effects and controls. Hansen J is not applicable (one excluded instrument for one endogenous regressor). bartik yearFE: first-stage coefficient 0.560032, $t = 29.333866$, t squared = 860.475679, excluded-instrument F = 860.475679; KP rk LM = 791.072 ($p < 0.001$). The same-sample OLS uses the same effects and controls. Hansen J is not applicable (one excluded instrument for one endogenous regressor). peer yearFE: first-stage coefficient 0.340335, $t = 12.873805$, t squared = 165.734865, excluded-instrument F = 165.734865; KP rk LM = 141.334 ($p < 0.001$). The same-sample OLS uses the same effects and controls. Hansen J is not applicable (one excluded instrument for one endogenous regressor). In dynamic one-step System GMM estimation ($N = 22{,}184$, 3045 firms), the Arellano–Bond AR(2) test ($z = -2.70$, $p = 0.007$) and Hansen overidentification test ($J(4) = 25.62$, $p < 0.001$) reject moment validity, so we rely on the static two-way fixed-effects baseline rather than System GMM.

Table A3. Balance in the actual unweighted matching regression sample.

Covariate	Bias Pre %	t Pre	p Pre	Bias Post %	t Post	p Post
FirmAge	−34.02	−27.027	<0.001	3.51	2.152	0.031
Mshare	7.66	6.148	<0.001	1.28	0.768	0.442
Board	4.13	3.318	<0.001	2.19	1.290	0.197
CashFlow	−6.10	−4.909	<0.001	0.28	0.161	0.872
Lev	−4.28	−3.451	<0.001	2.12	1.232	0.218
Top3	−2.93	−2.354	0.019	0.19	0.109	0.914
Dual	8.56	6.868	<0.001	0.69	0.406	0.685
Growth	5.65	4.564	<0.001	1.80	1.032	0.302
HHI	5.03	3.997	<0.001	−0.55	−0.329	0.742

Notes: Table A3 reports covariate balance before and after 1:1 nearest-neighbor propensity score matching (caliper = 0.05) for the matched regression sample (N = 13,544; 6679 treated and 6865 control observations). Mean absolute standardized bias decreases from 8.71% to 1.40%, Rubin's B falls from 36.94 to 5.77, and Rubin's R moves from 1.38 to 1.01.

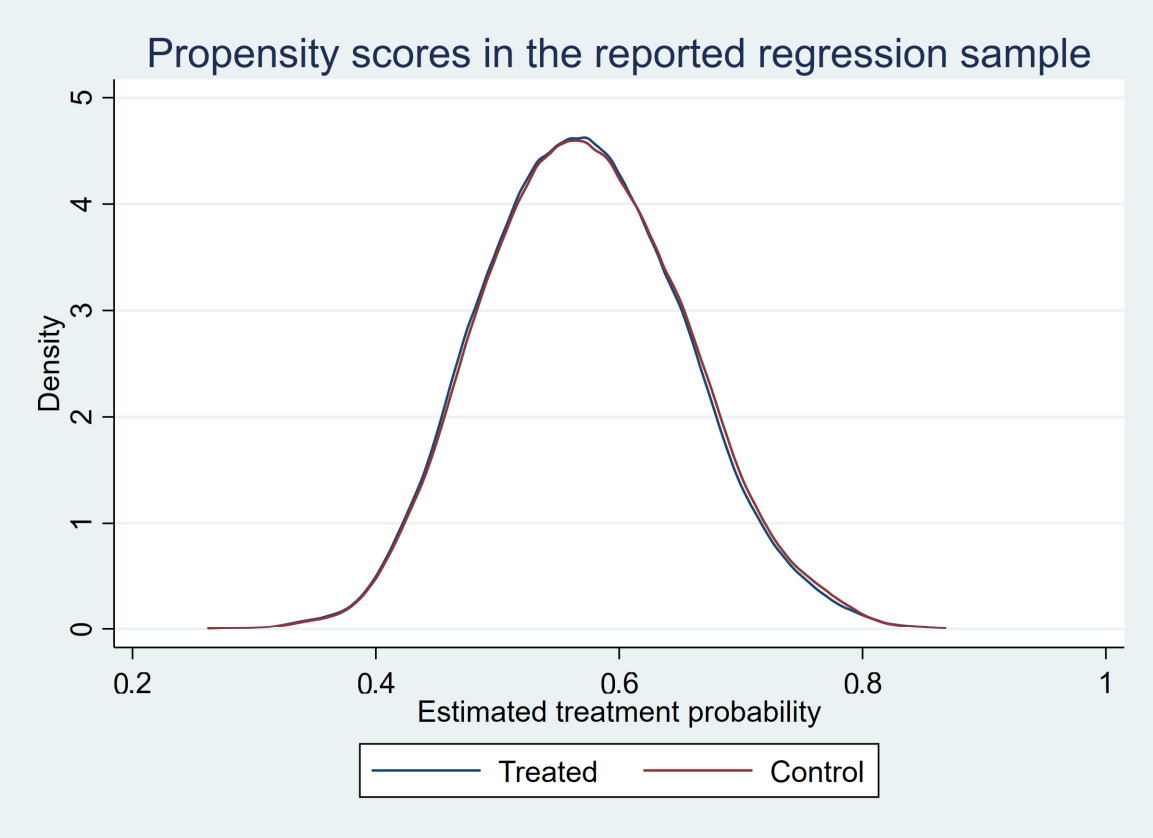

Figure A1. Kernel density overlap of estimated propensity scores for treated and control groups in the matched regression sample (N = 13,544).

Table A4. Conditional DESG slopes in the original moderation models.

Moderator	Point	Value	Slope	95% CI	*p*
Media	P25	3.8918	0.028092	[0.014394, 0.041791]	<0.001
Media	P50	4.5109	0.058523	[0.042398, 0.074648]	<0.001
Media	P75	5.0689	0.085956	[0.065818, 0.106093]	<0.001
ANALY	P25	0.0000	−0.105195	[−0.119019, −0.091371]	<0.001
ANALY	P50	1.3863	0.038686	[0.023476, 0.053895]	<0.001
ANALY	P75	2.3979	0.143678	[0.119727, 0.167629]	<0.001
ESP	P25	27.9900	−0.009048	[−0.023334, 0.005239]	0.215
ESP	P50	32.3300	0.041464	[0.026630, 0.056298]	<0.001
ESP	P75	36.6100	0.091277	[0.070197, 0.112358]	<0.001
GGR	P25	0.0000	0.025396	[0.004851, 0.045942]	0.015
GGR	P50	1.0986	0.053277	[0.037662, 0.068891]	<0.001
GGR	P75	1.7918	0.070867	[0.053233, 0.088501]	<0.001
NPRO	P25	0.0708	−0.017607	[−0.033333, −0.001881]	0.028
NPRO	P50	0.1215	0.036708	[0.021240, 0.052176]	<0.001
NPRO	P75	0.1627	0.080928	[0.061114, 0.100742]	<0.001

Notes: Table A4 reports the conditional marginal slope of EMV with respect to DESG ($\varphi_1 + \varphi_3\, m$) and its pointwise 95% confidence interval evaluated at the 25th (P25), 50th (P50), and 75th (P75) percentiles of each moderator in the estimation sample ($N = 26{,}486$), using the full variance–covariance matrix from Table 7.

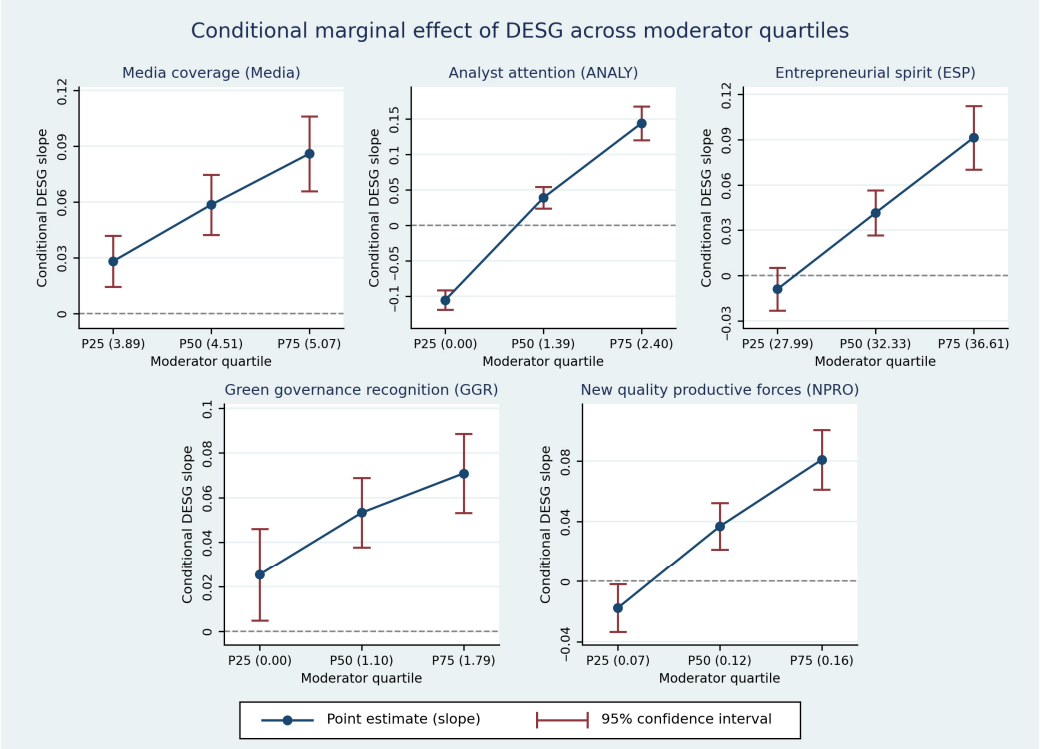

Figure A2. Conditional marginal effects of DESG on enterprise market value across the 25th (P25), 50th (P50), and 75th (P75) percentiles of each moderator with 95% confidence intervals (produced in Stata (Version 17.0), scheme s2color; $N = 26{,}486$).

Table A5. Revision stage multiplicity sensitivity.

Family	Focal Variable	Raw p	Holm p
moderation	Media	<0.001	<0.001
moderation	ANALY	<0.001	<0.001
moderation	ESP	<0.001	<0.001
moderation	GGR	<0.001	<0.001
moderation	NPRO	<0.001	<0.001
mechanism	XSA	<0.001	<0.001
mechanism	INA	<0.001	<0.001
mechanism	SA	<0.001	<0.001
mechanism	SZ	<0.001	<0.001
mechanism	SY	<0.001	<0.001

Notes: Table A5 reports raw and Holm step-down multiplicity-adjusted p-values across the five moderation tests (Table 7) and five first-link mechanism tests (Table 6). All ten focal relationships remain statistically significant at $p < 0.001$.

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