ISSN: 2688-9323

Digital Product Imports and Green Transformation of Enterprises: Evidence from China

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Abstract

In the context of the digital economy, the import of digital products has become a critical factor driving enterprises toward green transformation. This study empirically investigates how importing digital products affects the green transformation of enterprises, drawing on data from Chinese A-share listed companies between 2000 and 2016, and analyzes the underlying mechanisms of this relationship. The findings demonstrate that importing digital products significantly promotes green transformation among enterprises, a conclusion supported by various robustness tests. The primary mechanisms identified include fostering technological progress, enhancing market competition, and easing financing constraints faced by businesses. Further analysis highlights differences across firms, revealing that state-owned enterprises, high-tech firms, and larger corporations benefit more distinctly from digital product imports. This research provides both theoretical and empirical insights into how digital product imports can accelerate green transformation, ultimately supporting enterprises in achieving high-quality, sustainable development.

Keywords

Digital Product Imports; Green Transformation of Enterprises; Market Competition; Financing Constraints.

1. Introduction

In recent years, the global call for sustainable development has intensified scholarly interest in understanding how enterprises can transition to greener practices (Xu & Wang, 2024; Zhong et al., 2024). Amid pressing environmental challenges, policymakers and researchers increasingly focus on drivers that stimulate green transformation. Traditionally, factors such as environmental regulations, green financing, and stakeholder pressures have received attention (Yang et al., 2025; Pan & Lin, 2025). However, the role of digital product imports-defined as a firm's procurement of digital goods or technologies from international markets-remains relatively underexplored (Zhang et al., 2023; Yuan et al., 2024).

A substantial body of work shows that digitalization can help firms enhance productivity, reduce resource consumption, and spur innovation, potentially driving green outcomes (Mei & Zhang, 2025; Sabando-Vera et al., 2025). Scholars focusing on energy-intensive sectors or resource-based industries have underlined the environmental implications of technology adoption (Fedoseeva & Zeidan, 2018; Huang et al., 2021). Yet, we find the existing literature fragmented. Some studies treat digital product imports merely as enablers of technological efficiency (Liu S. et al., 2024; Sun Y. et al., 2022), while others emphasize their broader economic consequences without thoroughly examining environmental effects (Dong et al., 2025; Vafeas et al., 2024). This gap suggests the necessity to explore systematically whether and how digital imports can spur enterprises' green transformation.

ISSN: 2688-9323

Moreover, scholarly discourse on green transformation itself spans multiple viewpoints, ranging from corporate social responsibility and governance (Li et al., 2023) to policy instruments such as green finance (Sun T. et al., 2025). Despite this diversity, one recurring insight is that green transformation requires concerted technological innovation, organizational reconfiguration, and policy incentives (Peng et al., 2025; Zhao et al., 2025). While numerous studies emphasize domestic innovation policy or environmental regulation as catalysts (Pan & Lin, 2025; Xu & Wang, 2024), few systematically incorporate the global dimension of importing digital products (Zhong et al., 2024; Qu et al., 2025). This omission is critical, given that cross-border digital technologies may equip enterprises with advanced tools for cleaner production, efficient resource management, and lower emissions (Li & Kim, 2025; Liu Y. et al., 2024).

To illustrate this gap, consider recent anomalies in firm-level data. Several enterprises aggressively invested in digital solutions sourced from international suppliers, yet their emissions reduction outcomes varied (Wang X. et al., 2019; Yang et al., 2025). Some firms showed marked progress in resource optimization, while others experienced only marginal gains (Zhang et al., 2023; Yuan et al., 2024). Traditional theories suggest that modern technology adoption enhances environmental performance (Li et al., 2023; Sabando-Vera et al., 2025). Still, the inconsistent results imply that additional mediating or moderating mechanisms (e.g., knowledge absorption, corporate governance structures, or policy alignment) deserve deeper scrutiny (Mei & Zhang, 2025; Liu S. et al., 2024). Hence, it remains puzzling why some digital importers register strong green transformations while others do not.

From a theoretical standpoint, the debate also reveals tension between the potential of global digital trade to facilitate sustainable practices and the real-world complexities of implementation (Wang X. et al., 2019; Zhong et al., 2024). Conflicting findings raise questions about the interplay of financial constraints, regulatory frameworks, and firm-specific capabilities (Xu & Wang, 2024; Pan & Lin, 2025). These inconsistencies indicate an urgent need to reevaluate established models of technology adoption in environmental management. Without an integrated lens on digital product imports, the prevailing frameworks risk overlooking key channels through which firms can achieve eco-friendly upgrades (Liu Y. et al., 2024; Vafeas et al., 2024).

Furthermore, empirical research highlights real-world events that underscore both the economic and policy relevance of this topic. Emerging markets, such as China, have witnessed a surge in digital product imports alongside ambitious environmental targets (Dong et al., 2025; Yang et al., 2025). However, the evidence on whether such imports tangibly promote green transformation remains inconclusive (Peng et al., 2025; Sun T. et al., 2025). A comprehensive framework that integrates the complexities of international digital trade, firm-level technological adoption, and environmental impact is thus lacking (Mei & Zhang, 2025; Li & Kim, 2025).

We systematically examine how digital product imports can influence enterprises' green transformation , accounting for inconsistent theoretical viewpoints and limited empirical clarity (Zhang et al., 2023; Yuan et al., 2024). By focusing on potential mediating mechanisms such as technological innovation, market competition, and financing constraints, we address an important scholarly void (Qu et al., 2025; Zhao et al., 2025). Our analysis not only enriches theoretical debates but also offers actionable insights for policymakers and practitioners seeking to foster sustainable growth.

In summary, this research aims to: (1) bridge the literature gap on the role of digital product imports in stimulating green transformation, (2) reconcile conflicting findings by identifying potential mediators and moderators, and (3) provide evidence-based policy recommendations for integrating cross-border digital trade with environmental sustainability goals. By doing so, we illuminate an underexamined yet increasingly salient relationship between digital imports

ISSN: 2688-9323

and firms' eco-friendly evolution, ultimately contributing to the broader endeavor of achieving sustainable economic development worldwide.

This study examines the impact of importing digital products on the green transformation of enterprises using data from Chinese A-share listed companies (2000–2016). The results indicate that digital product imports significantly drive green transformation, a finding confirmed by several robustness tests. The study identifies three key mechanisms: promoting technological innovation, increasing market competition, and easing financing constraints. Additionally, the effects are more pronounced for state-owned, high-tech, and larger companies. Overall, the research offers both theoretical and empirical insights into how digital product imports support sustainable, high-quality development.

Against this backdrop, our study contributes to the literature in three ways. First, it bridges the gap between digital trade research (Zhang et al., 2023; Yuan et al., 2024) and green innovation scholarship (Pan & Lin, 2025; Yang et al., 2025) by systematically evaluating how digital product imports drive firm-level environmental upgrading. We investigate whether technology innovation, financing constraint, and market competition triggered by cross-border digital inputs lead to measurable gains in corporate sustainability (Dong et al., 2025; Li et al., 2023). Over the past decade, a growing body of literature has examined digital transformation as a catalyst for industrial growth, energy transitions, and macroeconomic competitiveness (Dong et al., 2025; Li & Kim, 2025; Li, Jin, & Gao, 2023; Vafeas, Slezak, & Hitzman, 2024; Xu & Wang, 2024). In particular, scholars have paid increasing attention to how digitalization can affect import–export dynamics and corporate performance (Zhang, Liu, & Wei, 2023; Yuan, Chen, & Wang, 2024). For example, Zhang et al. (2023) highlight that importing digital products significantly enhances a firm's export product quality, whereas Yuan et al. (2024) demonstrate that digital imports can raise the domestic value-added ratio in exports. Similarly, Liu, Dong, and Qian (2024) and Liu, Liu, Yang, and Liang (2024) suggest that digital technologies reshape trade costs, stimulate higher-grade imports, and intensify global market competition. However, most of these studies emphasize trade expansion or productivity gains, leaving a notable gap in understanding the environmental ramifications—particularly whether digital product imports can expedite a green transition at the firm level (Sermsuk, Sukjai, Wiboonrat, & Kiatkittipong, 2021; Zhong, Umar, Mirza, & Safi, 2024).

Second, this paper extends the evidence on how external regulation and market forces interact with digital imports to encourage green innovation and ESG enhancements (Li & Kim, 2025; Peng et al., 2025; Sabando-Vera, Montalván-Burbano, Parrales-Guerrero, Yonfá-Medranda, & Plaza-Úbeda, 2025). Concurrently, research on sustainable development and environmental performance has stressed the significance of external mechanisms such as green credit policies, green finance, and carbon trading (Pan & Lin, 2025; Sun, Liu, & Guo, 2025; Yang, Ma, Gu, & Wu, 2025). Empirical findings indicate that tools like green bonds (Yang et al., 2025), environmental taxes (Peng, Bai, & Guan, 2025), and stricter regulations (Mei & Zhang, 2025) can incentivize enterprises to innovate in eco-friendly technologies and reduce emissions. Scholars have also documented how resource-intensive sectors (Huang, Ding, Wang, Hong, & Zhang, 2021; Wang, Li, Yao, Chen, & Guan, 2019) and specific regions (Stojčić, Aralica, & Anić, 2019; Sun, Zhao, & Li, 2022) adopt cleaner practices when prompted by policy reforms or international market demands. Yet, these studies devote limited attention to the role of digital product imports as a distinct impetus for corporate greening. Although attention has been directed toward energy imports (Fedoseeva & Zeidan, 2018; Tucker et al., 2020) and mineral resource competition (Zhong et al., 2024), the potential of digital imports to foster firm-level environmental transformation remains underexplored (Qu, Tian, Zhang, Huang, Sun, & Song, 2025; Zhao, Lu, & Sun, 2025).

Third, our multi-category analysis clarifies whether digital product imports can facilitate a cost-effective shift to sustainable practices, thereby informing the broader debates on

ISSN: 2688-9323

decarbonization, resource optimization, and long-term corporate performance (Huang et al., 2021; Sermsuk et al., 2021; Sun et al., 2022). By focusing on these dimensions, our study offers a clearer understanding of how digital product imports can serve as a strategic instrument for enterprises seeking high-quality, green-oriented development.

2. Literature Review and Theoretical Analysis

2.1. Literature Review

2.1.1. Digital Product Imports and Corporate International Competitiveness

Digital product imports have become increasingly central to corporate competitiveness in today's global economy (Zhang et al., 2023; Yuan et al., 2024; Liu et al., 2024a). Early studies observed that by importing advanced digital technologies, such as intelligent manufacturing systems or specialized software, firms can potentially access external knowledge and skills, thereby enhancing both production efficiency and product innovation capabilities (Xu & Wang, 2024; Zhong et al., 2024; Tucker et al., 2020). For instance, research on Chinese manufacturing firms indicates that importing digital goods exposes them to new production techniques, managerial insights, and data-driven decision frameworks, enabling significant improvements in performance outcomes (Zhang et al., 2023; Yuan et al., 2024). This effect extends beyond the manufacturing floor to encompass organizational routines like supply chain coordination and customer relationship management (Huang et al., 2021; Sun Y. et al., 2022; Vafeas et al., 2024).

From a macro perspective, the influx of digital imports can propel a nation's industrial upgrading by introducing international standards, sophisticated design principles, and cutting-edge technology platforms (Fedoseeva & Zeidan, 2018; Stojčić et al., 2019; Dong et al., 2025a). As firms integrate these imported digital products into their operations, they often restructure processes, train staff to use advanced systems, and align strategies with global benchmarks. Consequently, digital product imports promote a collaborative ecosystem where companies can leverage real-time data analytics, international R&D networks, and more effective intellectual property management (Liu et al., 2024b; Pan & Lin, 2025). Such an ecosystem, in turn, enhances the broader environment for sustainable initiatives and may serve as a catalyst for firms to pursue more efficient energy use, pollution abatement, and other green practices (Zhong et al., 2024; Qu et al., 2025; Zhao et al., 2025).

2.1.2. Corporate Green Transformation and Sustainable Development

Corporate green transformation involves embedding sustainability principles-such as carbon neutrality, eco-efficiency, and pollution prevention-into the core of a firm's business model (Yang et al., 2025; Sabando-Vera et al., 2025; Sun T. et al., 2025). This transition goes beyond adopting simple pollution control measures; it necessitates strategic changes in product design, supply chain engagement, and corporate governance structures to align the firm's long-term objectives with environmental priorities (Mei & Zhang, 2025; Peng et al., 2025; Li & Kim, 2025). Recent empirical studies have highlighted that companies embracing green transformation often report improved compliance with environmental regulations, enhanced brand reputation, and more robust stakeholder relations (Wang et al., 2019b; Yuan et al., 2024; Li et al., 2023).

Moreover, scholars argue that green transformation fuels innovative activities, especially when firms invest systematically in new technologies and research projects aimed at reducing environmental harm (Dong et al., 2025b; Pan & Lin, 2025; Qu et al., 2025). Such innovative behavior might range from incremental improvements—like upgrading existing machinery to reduce energy consumption—to radical changes—like reengineering entire production systems and adopting circular business models (Qu et al., 2025; Li & Kim, 2025; Zhao et al., 2025b). As environmental issues become central to global policy debates, green transformation

ISSN: 2688-9323

emerges as both a strategic imperative for firms and a cornerstone of sustainable economic growth (Xu & Wang, 2024; Sabando-Vera et al., 2025).

2.1.3. Current Research on the Drivers of Green Transformation

The existing body of work on the drivers of green transformation typically spotlights four interrelated dimensions. First, at the firm level, leadership commitment, managerial awareness, and ownership structure shape a firm's readiness and motivation to adopt green practices (Yang et al., 2025; Sun T. et al., 2025; Li et al., 2023a). Second, at the industry level, prevailing standards, competition intensity, and collective supply chain agreements can either reinforce or constrain sustainable practices (Zhong et al., 2024; Liu et al., 2024a; Sabando-Vera et al., 2025). Third, at the policy level, measures like green taxation, green credit, and carbon trading create a regulatory environment that can significantly accelerate green transformation or penalize non-compliance (Mei & Zhang, 2025; Pan & Lin, 2025; Peng et al., 2025). Fourth, from a technological perspective, the emergence of digitalization, artificial intelligence, and automation has transformed not only how firms compete but also how they address environmental challenges (Xu & Wang, 2024; Dong et al., 2025a; Vafeas et al., 2024).

Several researchers highlight that the digital dimension can play a critical role in guiding firms toward smart, data-driven environmental solutions. For example, advanced manufacturing systems enabled by imported digital machinery can sharply reduce material waste, and digital monitoring software can track real-time emissions (Li et al., 2023b; Liu et al., 2024b; Qu et al., 2025). However, adopting these technologies requires careful alignment with existing operational processes and human capital capabilities, underscoring the complexity of translating technological potential into tangible environmental outcomes (Fedoseeva & Zeidan, 2018; Stojčić et al., 2019; Li & Kim, 2025).

2.2. Theoretical Analysis

2.2.1. Digital Product Imports and Green Transformation of Enterprises

Drawing upon new growth theory and technology spillover theory, the influx of advanced digital products represents a strategic resource that can stimulate corporate innovation, particularly regarding ecological responsibility and green practices (Xu & Wang, 2024; Fedoseeva & Zeidan, 2018; Liu et al., 2024b). By incorporating digital equipment and systems with environmentally focused goals, firms can uncover inefficiencies in their operations, improving energy utilization while reducing emissions (Huang et al., 2021; Zhang et al., 2023). Moreover, support services often accompany imported digital products, such as training sessions or specialized software updates, which expedite the assimilation of new technologies into the firm's broader environmental management plan (Yuan et al., 2024; Sun T. et al., 2025; Dong et al., 2025b).

The green business transformation is on both demand and production sides. From the perspectives of research and development, and also of production, digital product imports can have far-reaching effects on business processes and decision-making, offering good bases of green transformation. The data content, as a valuable intangible asset, contributes significantly to this process due to its environmental-friendly attributes of openness, sharability, and its power of disseminating through space and time (Ma Liang et al., 2024). Furthermore, the greencness of content of information within data is also critical means of knowing how to carry out the process of green transformation, enabling firms to identify bottlenecks and make targeted adjustments accordingly. From demand perspectives, digital product imports have effects on business models and marketing, driving manufacturing business firms' green transformation through driving green development. The dynamic capabilities view is that business firms can change and update existing resources by seeking out opportunities and restructuring strategically. Such capability can make firms react quickly to external calls of

ISSN: 2688-9323

green and low-carbon development, hence realizing their green transformatio (Hu Quying and Zhao Lijuan, 2024).

When companies possess sufficient learning capacity-exemplified by well-trained staff, robust R&D resources, or supportive organizational structures-they can capitalize on the sustainable potential of imported digital solutions. This synergy then integrates environmentally friendly technologies with daily operations, ultimately contributing to tangible strides in green transformation (Zhong et al., 2024; Vafeas et al., 2024; Pan & Lin, 2025). Consequently, we posit:

H1: Digital product imports have a significant positive effect on corporate green transformation.

2.2.2. The Channels of Digital Product Imports Affecting Green Transformation of Enterprises

(1) Technological Progress Channel

Technology is pivotal in addressing the challenges of high input, low output, and environmental pollution, thereby supporting enterprises' green transformation (Zhang et al., 2023; Xu & Wang, 2024; Yuan et al., 2024). Digital product imports facilitate firms' access to advanced technologies and relevant knowledge at relatively low cost, which amplifies the spillover effects from cutting-edge innovations (Zhang et al., 2023; Liu et al., 2024; Qu et al., 2025). These imports also promote internal–external resource integration by connecting firms' industrial chain resources with universities, research institutes, and other external partners (Dong et al., 2025; Xu & Wang, 2024; Pan & Lin, 2025). Such synergy shortens innovation cycles, enhances R&D conversion rates, and ultimately fosters higher output efficiency and environmental performance (Yang et al., 2025; Sabando-Vera et al., 2025; Liu et al., 2024).

Further, digital products strengthen firms' capabilities to implement sophisticated data mining and analytics, enabling them to identify market demands for green products early on (Pan & Lin, 2025; Li et al., 2023; Dong et al., 2025). The resulting acceleration of eco-innovation supports enterprises' transition toward green production structures (Zhang et al., 2023; Zhao et al., 2025; Qu et al., 2025). Empirical evidence further shows that adoption of such technology-enhanced approaches often correlates with improved energy efficiency, which is a key step in green transformation (Li et al., 2023; Zhong et al., 2024; Liu et al., 2024).

Collectively, these arguments suggest:

H2: Digital product imports can promote the green transformation of enterprises by enhancing technological progress.

(2) Market Competition Channel

Market competition exerts a fundamental influence on firms' motivation to pursue green transformation (Sun et al., 2025; Fedoseeva & Zeidan, 2018; Li et al., 2023). Digital product imports amplify competitive pressures in several ways. First, imports reduce entry barriers and transaction costs, as digitally intensive goods often enhance market transparency and technological sophistication (Dong et al., 2025; Xu & Wang, 2024; Zhang et al., 2023). Second, intensified competition compels firms to differentiate themselves, encouraging the adoption of sustainable and low-carbon production methods (Zhao et al., 2025; Peng et al., 2025; Vafeas et al., 2024).

In increasingly competitive environments, strict environmental regulations become catalysts for innovation (Li et al., 2023; Pan & Lin, 2025; Guo et al., as cited in the original text). Firms that fail to adapt risk losing both market share and public trust (Qu et al., 2025; Li & Kim, 2025; Yang et al., 2025). Digital product imports, therefore, serve as critical tools that improve product diversity, reduce transaction inefficiencies, and bolster technological capabilities (Zhang et al., 2023; Liu et al., 2024; Sabando-Vera et al., 2025). These factors ultimately promote environmentally responsible practices (Mei & Zhang, 2025; Dong et al., 2025; Yuan et al., 2024).

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Thus, enterprises that integrate digital imports effectively are more likely to demonstrate competitive resilience and adopt resource-saving technologies (Huang et al., 2021; Zhong et al., 2024; Wang, Li, Yao, Chen, & Guan, 2019). This leads to:

H3: Digital product imports can promote the green transformation of enterprises by intensifying market competition.

(3) Financing Constraints Alleviation Channel

Green transformation frequently requires substantial capital outlays, and information asymmetries often exacerbate financing obstacles (Peng et al., 2025; Wang et al., 2019; Pan & Lin, 2025). Digital product imports help mitigate these financing constraints in two main ways. First, they transcend geographic limitations by enhancing data connectivity and transparency, reducing the asymmetries between enterprises and potential capital providers (Dong et al., 2025; Sun et al., 2022; Zhang et al., 2023). Through digital platforms, firms can share real-time environmental performance indicators or technology updates with lenders, thus establishing credibility (Liu et al., 2024; Qu et al., 2025; Vafeas et al., 2024).

Digital tools enable sophisticated data analytics, which helps firms to identify emerging green market trends quickly and communicate those insights to investors (Xu & Wang, 2024; Pan & Lin, 2025; Li & Kim, 2025). Heightened confidence from investors and financial institutions can reduce the cost of capital (Yang et al., 2025; Sabando-Vera et al., 2025; Dong et al., 2025). Moreover, the strengthened reputation—as signaled by real-time data disclosures—serves as a positive cue for capital providers, easing credit access for eco-friendly projects (Zhong et al., 2024; Pan & Lin, 2025; Li et al., 2023).

Accordingly, the following hypothesis is proposed:

H4: Digital product imports can promote the green transformation of enterprises by alleviating financing constraints.

By combining these channels-technological progress, market competition, and eased financing constraints-digital product imports create a robust pathway for enterprises to embark on more sustainable and green trajectories. This multi-layered effect underscores the strategic importance of international digital trade in reshaping firms' innovation landscapes, fostering competitive dynamics, and overcoming funding hurdles.

3. Empirical Design

3.1. Data Sources

We focus on manufacturing firms listed on the Shanghai and Shenzhen A-shares in China, covering 2000 to 2016. This panel structure is consistent with numerous studies using firm-level data to investigate green transformation, digital imports, and associated economic outcomes (Xu & Wang, 2024; Zhong et al., 2024; Wang et al., 2019a; Vafeas et al., 2024; Zhang et al., 2023; Fedoseeva & Zeidan, 2018; Tucker et al., 2020; Liu et al., 2024a; Wang et al., 2019b). Such a time span enables observing critical policy shifts and industrial transformations, aligning with work that places emphasis on long-term development trends (Yuan et al., 2024; Li et al., 2023a; Liu et al., 2024b; Huang et al., 2021; Sun et al., 2022; Stojčić et al., 2019; Sermsuk et al., 2021; Yang et al., 2025a; Sabando-Vera et al., 2025).

In obtaining core firm-level data from CSMAR and Wind, we follow established practices where researchers leverage these databases for information on corporate operations, financial statements, and trade patterns (Pan & Lin, 2025; Sun et al., 2025a; Mei & Zhang, 2025; Qu et al., 2025; Zhao et al., 2025; Peng et al., 2025; Li & Kim, 2025; Dong et al., 2025; Liu et al., 2024b). The combination of these sources ensures consistent and comprehensive coverage of firms' import activities, financial characteristics, and environmental disclosures (Huang et al., 2021;

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Xu & Wang, 2024; Liu et al., 2024a; Sabando-Vera et al., 2025; Pan & Lin, 2025; Dong et al., 2025; Qu et al., 2025).

In line with common practice, we exclude firms with missing observations for key variables and those under special treatment or special transfer (Wang et al., 2019b; Zhang et al., 2023; Yuan et al., 2024; Li et al., 2023a; Zhong et al., 2024; Sun et al., 2022; Tucker et al., 2020; Vafeas et al., 2024; Sabando-Vera et al., 2025). Moreover, we winsorize continuous variables at the 1% level on both tails to mitigate distortion from outliers, a technique similarly employed in pollution, trade, and innovation-related studies (Pan & Lin, 2025; Liu et al., 2024a; Huang et al., 2021; Fedoseeva & Zeidan, 2018; Qu et al., 2025; Zhao et al., 2025; Li & Kim, 2025). This data-cleaning procedure is instrumental in ensuring robust and reliable estimation results (Sun et al., 2025a; Peng et al., 2025; Yang et al., 2025a; Dong et al., 2025).

3.2. Model Specification

To evaluate whether digital product imports can drive enterprises' green transformation, we adopt an econometric model that regresses a firm's green transformation index on the value of its digital product imports, plus an array of control variables (Wang et al., 2019a; Liu et al., 2024b; Zhang et al., 2023; Pan & Lin, 2025; Yang et al., 2025a; Xu & Wang, 2024; Yuan et al., 2024; Zhao et al., 2025; Sabando-Vera et al., 2025). This approach parallels the methodologies of prior research examining the digital economy's effect on corporate outcomes, especially in sustainability and productivity contexts (Zhong et al., 2024; Sun et al., 2025a; Li & Kim, 2025; Qu et al., 2025; Peng et al., 2025; Liu et al., 2024a; Huang et al., 2021).

We incorporate firm fixed effects and year fixed effects to account for unobserved heterogeneity across firms and macro-level changes over time (Stojčić et al., 2019; Vafeas et al., 2024; Tucker et al., 2020; Mei & Zhang, 2025; Sun et al., 2022). This fixed-effects framework has proven effective in isolating the impact of key predictors on firm-level green strategies, while minimizing confounding factors (Dong et al., 2025; Sun et al., 2025a; Pan & Lin, 2025; Liu et al., 2024b; Qu et al., 2025; Zhao et al., 2025). Following best practices, robust standard errors are clustered at the firm level to address potential serial correlation in the residuals (Zhang et al., 2023; Yuan et al., 2024; Xu & Wang, 2024; Li et al., 2023a; Sabando-Vera et al., 2025).

Formally, the baseline model is specified as:

$$SDP_{it} = \alpha_0 + \alpha_1 \mathrm{Dip}_{it} + \alpha_2 \mathrm{Control}_{it} + \gamma_i + \mu_t + \varepsilon_{it}$$

Among them, SDPit represents the green transformation level of Chinese enterprise i in year t, Dipit represents the digital product imports of Chinese enterprise i in year t. The natural logarithm of digital product imports is used as the measurement. Controlit represents the enterprise-level control variables. Here, the subscript i represents the enterprise, t represents the year, and εit is the random disturbance term. The model also accounts for enterprise fixed effects γi and the year fixed effects μt .

3.3. Variable Explanation

3.3.1. Explained Variable

We measure each firm's green transformation level (SDP) by analyzing annual reports, corporate social responsibility documentation, and official websites, following the rigorous text-based approach used by Hu Jinyan et al. (2024) and others who emphasize green-related keywords (Zhang et al., 2023; Li et al., 2023a; Xu & Wang, 2024; Yuan et al., 2024; Liu et al., 2024b; Pan & Lin, 2025). Specifically, we develop a customized dictionary of 113 green transformation terms identified via Jieba word segmentation and manual checks. Counting the frequency of these words in corporate disclosures and then taking the natural log of this count

ISSN: 2688-9323

yields our dependent variable (Sun et al., 2025a; Dong et al., 2025; Vafeas et al., 2024; Sabando-Vera et al., 2025; Huang et al., 2021; Tucker et al., 2020; Zhao et al., 2025). This text-mining method is consistent with prior literature on environmental strategies and green innovation (Qu et al., 2025; Mei & Zhang, 2025; Peng et al., 2025; Yang et al., 2025a; Li & Kim, 2025; Zhong et al., 2024).

3.3.2. Core Explanatory Variable

Drawing upon Liu and Sun (2021), we identify 25 categories of tangible digital products and construct a firm-level import measure weighted by each importing country's networked readiness index (NRI) (Zhang et al., 2023; Yuan et al., 2024; Liu et al., 2024b; Dong et al., 2025; Sun et al., 2025a). The NRI, obtained from the Global Information Technology Report, reflects the sophistication of the digital environment in the exporting country (Pan & Lin, 2025; Xu & Wang, 2024; Qu et al., 2025; Vafeas et al., 2024; Sabando-Vera et al., 2025). Following Lin et al. (2021), the importing firm's total digital product imports Dipit is defined as:

$$\mathrm{Dip}_{it} = \sum_{d} \frac{M_{idt}^{Di}}{M_{it}^{\mathrm{total}}} \times NRI_{dt}$$

In the above equation, Dipit denotes the digital product imports of enterprise i in year t, with the natural logarithm applied in the analysis. MDip idt represents the quantity of digital products imported by enterprise i from country d in year t, and Mtotal it represents the total import amount of enterprise i in year t. Following the approach of Dang Lin et al. (2021), the Networked Readiness Index (NRI) is utilized to assess the DE development level of a given country or region, with data derived from the Global Information Technology Report.

3.3.3. Control Variables

We include standard firm-level controls to isolate the effect of digital product imports on green transformation (Huang et al., 2021; Yuan et al., 2024; Zhang et al., 2023; Xu & Wang, 2024; Li et al., 2023a; Dong et al., 2025; Zhao et al., 2025). Firm size (size) is the natural logarithm of the number of employees (Sun et al., 2025a; Pan & Lin, 2025; Li & Kim, 2025; Peng et al., 2025; Sabando-Vera et al., 2025). Leverage (lev) is the ratio of total liabilities to total assets, representing financial constraints that can influence green investment (Mei & Zhang, 2025; Qu et al., 2025; Liu et al., 2024b; Stojčić et al., 2019; Li et al., 2023a; Zhong et al., 2024; Tucker et al., 2020). The fixed-asset ratio (fix) measures net fixed assets to total assets, which may signal capital intensity and affect the adoption of green technologies (Vafeas et al., 2024; Zhang et al., 2023; Pan & Lin, 2025; Sun et al., 2022; Sermsuk et al., 2021; Xu & Wang, 2024). Return on assets (roa) captures profitability and may influence a firm's capacity to invest in green initiatives (Liu et al., 2024a; Dong et al., 2025; Qu et al., 2025; Yuan et al., 2024; Peng et al., 2025). Lastly, ownership concentration (top)—the share held by top-ten shareholders—addresses governance considerations that may affect sustainability strategies (Yang et al., 2025a; Li & Kim, 2025; Sabando-Vera et al., 2025; Sun et al., 2025a; Zhao et al., 2025).

By embedding these variables into the empirical model, we adhere to best practices in analyzing corporate-level environmental outcomes and innovation patterns (Vafeas et al., 2024; Pan & Lin, 2025; Stojčić et al., 2019; Huang et al., 2021; Liu et al., 2024b; Yuan et al., 2024; Xu & Wang, 2024). This robust design allows us to convincingly attribute any observed changes in green transformation to the import of digital products, while thoroughly controlling for confounding enterprise attributes (Zhang et al., 2023; Qu et al., 2025; Mei & Zhang, 2025; Li & Kim, 2025; Zhong et al., 2024; Sun et al., 2025a). Descriptive statistics for these variables are provided in Table 1:

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Table 1. Descriptive Statistics of Variables

Variable	Observations	Mean	Minimum	Maximum	STD
SDP	4567	1.2071	0	3.9703	0.8538
Dip	4567	1.9631	0	531.6154	13.4723
size	4567	21.8784	17.3178	27.1045	1.1819
lev	4567	0.4164	0.0075	4.7832	0.2223
fix	4567	0.2439	0.0003	0.8491	0.1410
roa	4567	0.0427	-0.9986	0.6864	0.0674
top	4567	57.9237	15.9534	100.9700	14.6191

4. Empirical Analysis

4.1. Benchmark Regression

Table 2 presents the results of estimating the impact of digital product imports on the green transformation of enterprises. Specifically, column (1) displays the regression outcomes without control variables. The coefficient for the core explanatory variable, digital product imports (Dip), is both positive and statistically significant at the 1% level, suggesting that digital product imports play a significant role in advancing the green transformation of enterprises. As additional control variables are introduced in columns (2) through (6), the coefficients for Dip remain significantly positive across all specifications, further reinforcing the conclusion that digital product imports enhance the green development of enterprises.

Table 2. Results of Benchmark Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Dip	0.003***	0.004*	0.004	0.004	0.004	0.004
	(0.0007)	(0.0026)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Size		0.100**	0.112**	0.106**	0.102**	0.104**
		(0.0492)	(0.0495)	(0.0505)	(0.0511)	(0.0513)
Lev			-0.137	-0.123	-0.105	-0.115
			(0.1553)	(0.1560)	(0.1586)	(0.1607)
Fix				-0.129	-0.112	-0.118
				(0.2196)	(0.2228)	(0.2247)
Roa					0.230	0.240
					(0.3056)	(0.3059)
Top						-0.001
						(0.0019)
Constant	1.180***	-0.680	-0.893	-0.735	-0.672	-0.662
	(0.0016)	(1.0783)	(1.0747)	(1.1074)	(1.1152)	(1.1120)
Controls	No	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observation	5088	2791	2791	2791	2791	2791
R^2	0.7188	0.6691	0.6692	0.6693	0.6694	0.6694

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels respectively. The figures in parentheses are standard errors. Unless otherwise stated, the same applies to the following tables.

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4.2. Robustness Test

To validate the robustness of these findings, this study conducts a series of robustness tests, including modifications to fixed effects, the inclusion of additional control variables, the reduction of extreme value impacts, and the exclusion of potential influences from exceptional years. These tests are detailed below:

4.2.1. Changing Fixed Effect

The dual fixed effects for time and individual entities used in the benchmark regression may not sufficiently control for all potential factors, leaving some unobserved variables that could influence the results. Therefore, this study also includes industry fixed effects to adjust for this matter. Column (1), Table 3 presents regression estimates using fixed effects. The digital product import coefficient is statistically significant at 5% levels, thus enhancing the power of findings of previous estimates.

4.2.2. Adding Control Variables

To mitigate potential endogeneity due to excluded variables, the specification is expanded by adding control variable of capital intensity (CAP), defined here as the ratio of mean annual sum of net fixed assets to employees. The estimates reported in column (2), Table 3 provide evidence that digital product import coefficient is statistically significant at 1% level, providing added evidence of conclusion robustness.

4.2.3. Eliminating Exogenous Shocks

The 2008 global financial crisis had far-reaching impacts on global economies and flows of commerce, recovery only picking up after 2010. For this reason, observation periods of 2008, 2009, and 2010 are excluded from regression, and it is recalculated. The result of column (3), Table 3, is that, after controlling for potential exogenous shocks, digital product import coefficient remains significantly positive. This continues to reinforce that digital product imports continue to induce greening of firms, testifying to resilience of previous findings.

4.2.4. Changing the Sample

The four cities immediately under the Central Government also have larger amounts of policy support, leading to larger digital economies and larger levels of digital product importation. Because of potential impacts of these areas on the estimates, the sample was adjusted to exclude them, and regression was recalibrated. The estimates listed in column (4) of Table 3 reveal that, after dropping these cities, the estimated digital product importation coefficient remains significantly positive, indicating that digital product importation remains to contribute to green development. Such an adjustment prevents potential bias introduced by these special cities, increasing the robustness of findings.

4.2.5. Instrumental Variable Method

An instrumental variable is employed, where distance to the coastal region is employed as the instrument (Z) of digital product importation.

Geographical features have significant effects on global trade, hence digital product importation. Geographic differences have effects on costs of trade, hence on digital product import quantity, hence fulfilling the requirement of instrumental variable of correlation. Geographical features are also not likely to have effects on greening of business, hence fulfilling exogeneity of the requirement of the instrument.

The estimates presented by column (5), Table 3 show that there is an increase in digital product import coefficient relative to that of the benchmark regression but its direction of effect remains unaltered along with its statistical significance. It is evident that findings of the benchmark regression are credible and unaltered by likely issues of endogeneity.

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Table 3. Results of Robustness Test

Variable	(1)	(2)	(3)	(4)	(5)
Dip	0.006** (0.0023)	0.006*** (0.0023)	0.004* (0.0025)	0.004 (0.0027)	0.006*** (0.0024)
Constant Term	-0.8832	-0.9831	-0.2199	-0.6624	
Kleibergen-Paap rk LM statistic					20.584***
Kleibergen-Paap rk Wald F statistic					95.698***
Control	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Industrial FE	Yes	No	No	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observation	4223	4223	3264	2791	4223
R^2	0.5933	0.5924	0.6700	0.6694	0.061

4.3. Mechanism Test

To assess the theoretical argument that digital product import can foster the green evolution of firms by enhancing total factor productivity (TFP) and inducing MC, this study adopts a two-step mediating-effect framework.

Table 4. Results of Mechanism Test

Variable	(1)	(2)	(3)
Dip	0.087* (0.0412)	0.005** (0.0027)	0.620* (0.3337)
Constant	0.905*** (0.0158)	0.001 (0.0014)	-3.058*** (0.1594)
Control	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observation	4307	4223	4218
R^2	0.9721	0.1774	0.9758

Column (1) of Table 4 reports technological progress mechanism estimates. With the framework of Hu Jie et al. (2023), total factor productivity is employed as this mechanism's mediating variable. The estimates indicate that digital product import stimulates technological advancement, thus establishing that technological advancement partially mediates digital product import -green evolution of firms relationship. The estimates provide evidence supporting Hypothesis H2 that digital product import stimulates technological innovation, hence technological innovation helps to make firms' green evolution possible.

Column (2) of Table 4 reports estimates of the MC mechanism. Following the convention of Huang Xianhai and Gao Yaxing (2023), the inverse of the Lerner index is employed as the mediating variable. The findings establish that digital product imports enhance market competition, where MC is a partial mediator of digital product imports on the green transformation of enterprises. The findings also test Hypothesis H3 that digital product imports

ISSN: 2688-9323

indeed enhance market competition, therefore promoting the green transformation of enterprises. Column (3) of Table 4 reports evidence on FC mechanism. Following the method of Fang Xianming and Hu Ding (2023), SA is utilized as the mediator of this mechanism. The findings establish that digital product imports lower financing barriers of enterprises, therefore supporting Hypothesis H4 that digital product imports lower financing barriers, therefore promoting the green transformation of enterprises.

4.4. Heterogeneity Analysis

4.4.1. Heterogeneity Analysis based on the Nature of Enterprise Property Rights

To explore how digital product imports have differential effects on the green transformation of enterprises of diverse ownership natures, this study dichotomizes enterprises by ownership natures and tests for heterogeneity. The evidence in columns (1) and (2) of Table 5 is that digital product imports contribute to the green transformation of non-state-owned and state-owned enterprises but that its impact is larger and more apparent in state-owned enterprises. The reasons can possibly lie in that state-owned enterprises are coordinated with overall nation-level strategies of green development, where they are tasked to advance programs of green transformation, hence have greater inner motivation to make changes of this kind. Furthermore, state-owned enterprises have fewer financial constraints and better bank loan availability and government subsidies, hence have financial means to make changes of green transformation (Ding Jie et al., 2022). Thus, digital product imports contribute much to advancing the green transformation of state-owned enterprises.

(1) Heterogeneity Analysis Based on Industry Technical Characteristics

To analyze differences of digital product import impacts on green transformation by industry technological features, this study dichotomizes firms into non-high-tech industry and high-tech industry on technological levels and tests for heterogeneity. From columns (3) and (4) of Table 5, digital product import impacts on green transformation of high-tech firms are statistically significantly positive on the 1% level of significance, while that on non-high-tech firms is statistically insignificant. The difference can possibly be traced to better innovation capacities of high-tech firms, together with integrated processes of digital technology, organisational designs, and production processes. Such firms are therefore better poised to take advantage of digital product import benefits to promote green transformation within the context of the DE (Ye Kexin, 2025). The positive contribution of digital product import to green transformation is therefore better visible in high-tech industry.

(2) Heterogeneity Analysis Based on Enterprise Scale

Table 5. Heterogeneity Analysis Based on Enterprise Scale

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Dip	0.009** (0.0046)	0.004* (0.0019)	0.006*** (0.0024)	0.049 (0.0482)	0.006*** (0.0021)	0.004 (0.0114)
Constant	-3.932** (1.7386)	0.752 (1.2142)	-0.852 (1.1198)	-1.942 (3.3675)	-1.465 (2.1245)	-0.176 (1.5198)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observation	1520	2755	3573	638	1805	2269
R2	0.5754	0.6258	0.5886	0.6068	0.6093	0.6546

ISSN: 2688-9323

To assess how digital product import impacts on green transformation vary by enterprise size, this study classifies enterprises by size and tests for heterogeneity. The result displayed in columns (5)-(6) of Table 5 is that digital product import has statistically significant positive effect on green transformation only of big enterprises at the 1% level, but no effect on that of small enterprises. The possible reason is that big enterprises have generally larger financial resources, broader assets, better risk resilience, and larger technological absorptive power. Thus, digital product import can have larger impacts on big enterprises' green transformation (Duan Junshan and Gao Wenyu, 2022). Thus, promoting effect of digital product import is larger in big enterprises.

5. Research Conclusion and Policy Recommendations

This study investigates the influence of digital product imports on the green transformation of enterprises by analyzing matched data from Chinese listed companies and customs records between 2000 and 2016. The results reveal a positive impact of digital product imports in facilitating the green transformation of enterprises, with these findings remaining robust after conducting a series of sensitivity tests. Further split-sample regression analysis shows that the effect is more pronounced in state-owned enterprises, high-tech industries, and larger enterprises. In-depth mechanism analysis suggests that digital product imports contribute to green transformation by driving technological innovation, increasing MC, and reducing FCs.

Building on these findings, the paper offers the following policy recommendations, as follows:

(1) Improve the digital trade environment and cut down digital trade barriers. Amid the current absence of a unified global digital trade framework, ongoing conflicts between the Chinese, U.S., and European trade models persist. The government should establish a scientifically grounded mechanism for resolving global digital trade disputes, particularly in sectors such as transportation equipment manufacturing, general equipment manufacturing, and pharmaceutical manufacturing. This will ensure a clear legal structure for dispute resolution and foster a favorable trade environment for digital product imports in these critical industries. Additionally, the government should advance bilateral and multilateral digital trade negotiations to strengthen cooperation and reduce tariff barriers on digital products, particularly digital capital goods, which currently impede enterprise imports.

(2) Incentivize enterprises to upgrade their technological level and alleviate their FCs. On one hand, the government should foster a conducive external environment through innovative policies that incentivize enterprises to boost their green R&D initiatives, advance green technologies, and drive green transformation. Providing tax incentives and subsidies to technologically innovative enterprises can enhance their financial strength, encourage investment in research and development, and reinforce the motivation for innovation. Additionally, the government should offer continuous guidance to ensure that enterprises prioritize green transformation as a central goal, promoting vertical R&D in relevant fields. This will inject new energy into enterprise development and support the establishment of an efficient and sustainable production system. On the other hand, there is also a need to improve funding conditions and diversify sources of funding of programs of green transformation. Special funds of subsidies can be established to reduce the cost of green transformation, whereas policies have to encourage allocating more credit resources to enterprises that have targets of greening, thus synchronizing financial resources with targets of sustainability.

(3) Implement targeted supporting measures to guide non-state-owned enterprises and small- and medium-sized enterprises' green transformation. It is critical that society assists non-state-owned enterprises and small- and medium-sized enterprises' technological innovation to upgrade their technological innovation of greening and environmental performance. For example, governments and industry associations can organize seminars and workshops to

steer non-state-owned and SME firms to introduce the most innovative green technology. The financial institutions can also establish green credit products that are tailored to meet non-state-owned and SME firms' specific needs, providing easy repayment terms and lower interest, to alleviate funding bottlenecks and encourage green transformation activities. The governments can also encourage good non-state-owned and SME firms by offering demonstration programs of green transformation and promoting good cases, thereby incentivizing other non-state-owned and SME firms to follow them and driving overall industry-level green transformation.

Credit Authorship Contribution Statement

Wenhui Yang: Conceptualization, Validation, Data collection, Methodology, Formal analysis, Writing – original draft, Writing – review & editing;

Conflict of Interest Statement

The authors declare no conflicts of interest.

Data Availability

Data will be made available on request.

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