Do Business and Trade Facilitation Journal
Volume 5, Issue 1, 2025, Page 14-26
https://doi.org/10.6914/dbtf.050102

Do Business and Trade Facilitation Journal

Digital Leviathan or Green Catalyst? Deconstructing the Mechanisms, Paradoxes, and Governance of the Global Green Trade Transformation

Chi FAN
School of Business, Qilu University of Technology

Abstract

This paper examines how digital technologies shape the systemic transformation of global green trade. It develops a three-dimensional framework—production, distribution, and market/governance—to show how digitalization acts not only as a tool but as a catalyst for structural change. At the production end, AI and big data foster green innovation; in distribution, blockchain and IoT build technical trust to reduce information asymmetry; at the governance level, digital platforms create feedback loops between market demand and regulatory pressure. Yet this transformation entails a "double-edged sword": rising energy use, e-waste, and competition for critical minerals reveal the environmental footprint of digitalization, while the digital divide combined with green trade measures produces new "stacked barriers" for developing economies. Comparing the strategic paths of the EU, China, and the US, the study argues for coordinated, multi-level governance built on interoperable standards such as carbon accounting and the Digital Product Passport to promote inclusive and sustainable trade.

Keywords Green Trade; Digitalization; Global Governance; Double-Edged Sword; Stacked Barriers; Digital Product Passport

1 Introduction

1.1 The Converging Digital and Green Revolutions

The global economy is experiencing two profound and parallel structural transformations: the digital revolution, driven by AI, big data, and the Internet of Things, and the green revolution, which focuses on combating climate change and promoting sustainable development. These trends are not evolving in isolation but are deeply intertwined, shaping the future of global resource allocation, international economic structures, and geopolitical competition. Against this backdrop, international trade, the lifeblood of the global economy, stands at the historic intersection of this dual digital and green transition. Leading international organizations have underscored the transformative potential of this convergence. Recent reports from the World Trade Organization (WTO), the United Nations Conference on Trade and Development

Article History Received: April 15, 2025; Accpted: June 6, 2025; Published: June 30, 2025. ***Do Business and Trade Facilitation Journal***, ISSN 2789-3944 (Print), ISSN 289-3952 (Online),published by Creative Publishing Co., Limited 2025.. Email: wtocom@gmail.com, https://dbtf.cc, https://cpcl.hk.

(UNCTAD), and the Organisation for Economic Co-operation and Development (OECD) highlight that digital technologies possess immense capacity to reduce trade costs, reconfigure global value chains, and thereby provide a powerful impetus for achieving the United Nations' 2030 Sustainable Development Goals (SDGs). The WTO's 2025 World Trade Report, for instance, projects that artificial intelligence alone could significantly increase global trade by as much as 37% by 2040, primarily by reducing operational costs and boosting productivity.2 This optimistic outlook positions digitalization as a key enabler of a more efficient and, potentially, a more sustainable global economic system.

1.2 The "Double-Edged Sword": From "Whether" to "How"

The discourse has shifted from simply questioning "whether" digital technology can support green objectives to exploring "how" it achieves these goals, what "consequences" it brings, and who benefits. This study focuses on the "double-edged sword" effect, critically analyzing the negative externalities and systemic risks often overlooked in techno-optimistic narratives. Prevailing techno-determinist perspectives have historically paid insufficient attention to the inherent contradictions of the digital-green nexus. The assumption that digital efficiency automatically translates into environmental sustainability is a dangerous oversimplification that ignores the material realities of the digital economy and the complex socio-economic systems in which it is embedded. Therefore, the core analytical perspective of this paper is to move beyond simple causal judgments and construct a comprehensive theoretical framework. This framework is designed to systematically dissect the intrinsic mechanisms, complex effects, and governance challenges of the digital-driven green trade transformation. By doing so, it aims to provide a more nuanced and realistic assessment of the opportunities and perils that lie ahead, offering a foundation for policies that can navigate the inherent trade-offs and steer the global trade system toward a genuinely sustainable and inclusive future.

1.3 Research Framework, Core Contributions, and Structure

To address the aforementioned research questions, this paper constructs an integrated analytical framework of a "Transformation Trilogy" (production, distribution, market/governance). This framework allows for a systematic examination of how digitalization permeates the entire trade lifecycle, from the creation of a product to its final consumption and the regulatory environment that governs it. The core contributions of this study are threefold. First, it provides a systematic, integrated theoretical framework that reveals the multi-dimensional transmission pathways of the transformation, moving beyond siloed analyses of technology or trade policy. Second, it conducts an in-depth, data-driven analysis of the inherent paradoxes of the transformation process, particularly its environmental footprint and the novel "stacked barriers" risk proposed herein, which highlights the potential for digitalization to exacerbate global inequality. Third, it offers a geopolitical analysis of competing governance models adopted by the European Union, China, and the United States, providing a theoretical basis for forging a path of global cooperation in an era of increasing regulatory fragmentation. The paper is structured as follows: Section 2 presents the literature review and theoretical foundation. Section 3 builds the analytical framework and elaborates on its core mechanisms. Section 4 deeply analyzes the "double-edged sword" effects of the transformation. Section 5 discusses global governance and policy paths. Finally, Section 6 provides conclusions and prospects for future research.

2 Literature Review and Theoretical Foundation

2.1 The Evolution of Green Trade

The concept of "green trade" has undergone a significant evolution. Initially, its scope was narrow, focusing primarily on the trade of Environmental Goods and Services (EGS), such as wind turbines or wastewater management services. Over time, the definition has expanded into a broader, multi-layered framework whose core objective is to internalize the environmental externalities of all trade activities and steer global production and consumption patterns toward sustainability. Scholars have attempted to quantify this shift by developing indicators like the "Green Trade Openness Index (GTOI)," which typically measures the share of green product imports and exports in a country's total trade, offering a metric for national participation in the green economy. However, the practice of green trade has always been fraught with the challenge of "green protectionism," where environmental standards are perceived or used as non-tariff barriers to trade. This tension has been exacerbated in recent years by the emergence of new and complex policy instruments. The European Union's Carbon Border Adjustment Mechanism (CBAM) is a paradigmatic example. By imposing a levy on the embodied carbon of certain imports, CBAM aims to prevent "carbon leakage" but has also been criticized by developing countries as a unilateral measure that could unfairly penalize their exports. Such instruments have further complicated the intricate interplay between trade and climate politics, placing them at the center of contemporary challenges in global trade governance.

2.2 Digital Disruption of International Trade

Concurrently, digital technology is fundamentally altering the methods, subjects, and structure of Global Value Chains (GVCs). The digitalization of trade processes—from automated customs clearance to digital documentation—has significantly lowered transaction costs, making international trade more accessible, particularly for small and medium-sized enterprises (SMEs). Furthermore, new trade subjects, such as digitally delivered services, are growing at an exponential rate, reshaping the composition of global trade flows. At the value chain level, data flows are becoming as critical as the flow of goods, enabling more precise and refined divisions of labor and just-in-time production systems. This process, however, is not universally beneficial. UNCTAD reports have consistently highlighted the existence of a significant "digital divide" in terms of digital infrastructure, investment, and capabilities. Recent data underscores this disparity: between 2020 and 2024, developing countries received just 30% of global greenfield investment in the digital economy, and within this group, 80% of that investment was concentrated in just ten countries, primarily in Asia. Core digital infrastructure remains severely underfunded in many parts of the world, particularly in the least developed countries, which remain on the margins of the digital economy. Consequently, developed economies continue to dominate global digital services trade, while many developing countries risk further marginalization due to a lack of capital, technology, and talent.

2.3 A Critical Synthesis and Identified Gaps

Existing research at the intersection of digitalization and greening has largely confirmed a positive correlation between the two at both the firm and regional levels. Studies have identified various mechanisms through which this occurs, such as digitalization easing financing constraints for green projects and enhancing the efficiency of innovation processes. Despite these contributions, there are clear gaps in the current literature that this paper seeks to address. First, most studies lack an integrated analytical framework that places digital technology and green innovation within the specific context of "international trade." They often analyze the digital-green nexus in a domestic or regional setting, failing to systematically answer how digital technology drives the "green transformation" of "trade" itself, with its unique cross-border complexities. Second, existing research pays insufficient attention to the complexities and negative effects of the transformation process. The environmental costs of digitalization itself, the potential economic paradoxes it may trigger (such as the rebound effect), and its complex interactions with international trade policies have not been systematically explored in an integrated manner. This study aims to fill these research gaps by providing a holistic framework that accounts for both the enabling mechanisms and the inherent contradictions of the digital-driven green trade transformation.

3 The Transformation Trilogy: A Theoretical Framework and Its Mechanisms

3.1 An Integrated Analytical Framework

To systematically explain how digital technology drives the green trade transformation, this paper constructs an integrated three-dimensional transmission mechanism framework, termed the "Transformation Trilogy." This framework posits that the enabling effect of digital technology is not linear but rather systematically permeates and reshapes three key levels of the trade activity chain: the production end, the distribution process, and the market and governance end. By acting on these three dimensions simultaneously, digitalization synergistically drives the entire trade system towards a green and sustainable evolution. These three mechanisms are interconnected and build on one another to form a holistic transformation process. Empowerment at the production end creates the supply of credible green products. The restructuring of the distribution process provides the means to verify and trust the green claims of these products across borders. Finally, the shaping of the market and governance end creates the demand and regulatory pull for these trusted green products, completing a virtuous cycle. This integrated logic is summarized in Table 1.

Table 1: The Transformation Trilogy: Mechanisms, Pathways, and Impacts (Summary)

Dimension/Mechanism	Core Driving Technologies	Key Transmission Pathways	Impact on Green Trade
I. Production-End Empowerment	AI, Big Data, Digital Twin	1. Drive green tech innovation 2. Optimize resource allocation: real-time monitoring 3. Promote green investment	- Enhance green product competitiveness - Reduce embodied carbon in trade
II. Distribution Process Restructuring	IoT, Blockchain, GIS	1. Enhance supply chain transparency 2. Optimize green logistics 3. Foster circular economy: reverse logistics	- Increase credibility of green supply chains - Lower international distribution costs - Shift trade model from linear to circular
III. Market & Governance Shaping	Digital Platforms, Remote Sensing	1. Empower green consumption 2. Innovate environmental governance 3. Enhance trade policy enforcement	- Expand global demand for green products - Strengthen enforcement of environmental regulations - Provide solutions for "carbon leakage"

3.2 Mechanism I: Empowering Green Innovation at the Source (Production End)

The impetus for the digital-driven green trade transformation originates in its profound reshaping of the production end, where goods are designed and manufactured. Traditional green research and development

(R&D) is often hampered by high investment requirements, long development cycles, and significant material waste during trial-and-error phases. Digital technologies such as Artificial Intelligence (AI) and digital twins offer a systematic solution to these challenges. Companies can now create virtual replicas of production processes and products, allowing them to simulate and optimize new energy-saving manufacturing techniques or test the lifecycle performance of sustainable materials in a virtual space. This dramatically shortens R&D cycles, reduces physical prototyping costs, and accelerates the pace of green innovation. Concurrently, the deployment of the Internet of Things (IoT) transforms production management from a static to a dynamic process. Through IoT sensors deployed on production lines, companies can monitor energy consumption, water usage, and pollutant emissions in real-time. This data allows for continuous dynamic optimization, reducing waste and improving the environmental performance of products, which are then better aligned with international green standards. By generating granular, real-time data on resource efficiency, firms can not only cut costs but also substantiate their green credentials to international buyers and regulators, thereby enhancing the competitiveness of their exports in an increasingly environmentally conscious global market.

3.3 Mechanism II: Building Trust Through a Transparent Green Value Chain (Distribution Process)

If production-end empowerment solves the "supply" issue of green products, the digital restructuring of the distribution process aims to address the core challenges of "trust" and "efficiency" in green trade. A key barrier to the growth of green trade has been information asymmetry; consumers and regulators often have no reliable way to verify the environmental claims made about products sourced from complex, opaque global supply chains. The combination of the Internet of Things (IoT) and blockchain technology offers a revolutionary solution to this problem. The technical workflow is as follows: IoT sensors automatically collect environmental data at key nodes of the supply chain, such as at the raw material origin (e.g., soil moisture on a sustainable farm) or within the production workshop (e.g., energy consumption per unit). This data is then cryptographically hashed and uploaded in real-time to a distributed, immutable ledger based on blockchain. This creates an auditable 'digital ledger' for the product's entire lifecycle, offering transparency and accountability at each stage, from raw material sourcing to retail. A consumer or a customs official can simply scan a QR code on the product to trace its journey and verify the authenticity of its green claims. This mechanism fundamentally shifts the paradigm from "institutional trust," which relies on costly and sometimes fallible third-party certification bodies, to "technical trust," which is based on verifiable, time-stamped, and tamper-proof data. This technological logic is at the very core of emerging regulatory frameworks like the European Union's mandatory "Digital Product Passport (DPP)" initiative. The DPP will require specific products entering the EU market, such as batteries and textiles, to carry a digital passport detailing their material composition, carbon footprint, reparability, and recycling information. This implies a profound shift: digital capability itself is becoming a condition for green trade access. Whereas traditional trade barriers focused on the physical attributes of products, new regulations like CBAM and the DPP emphasize the verifiability of production process attributes. Cross-border process verification relies entirely on traceable data chains and mutually recognized digital standards, thereby merging digital compliance with green compliance.

3.4 Mechanism III: Cultivating Green Demand and Reshaping Environmental Governance (Market and Governance End)

Digital technology not only drives transformation from the supply side (production and distribution) but also plays a crucial shaping role on the demand side and in the broader institutional environment. Digital platforms, such as e-commerce marketplaces and social media, have become powerful tools for empowering and amplifying the force of green consumption. Through features like eco-labels, sustainability filters, and transparent product review systems, these platforms deliver complex environmental information to consumers in an intuitive and accessible manner, enabling them to make more informed purchasing decisions and creating market pull for sustainable products. More importantly, digital technology is becoming an indispensable infrastructure for the implementation of modern, complex environmental regulations. The EU's CBAM provides a compelling case in point. The core technical challenge of CBAM is not the policy concept itself, but its execution: accurately calculating and verifying the "embodied carbon emissions" of thousands of different products imported from dozens of countries with varying accounting methodologies. This process involves immensely complex transnational data collection, verification, and reporting. Without the support of a unified digital reporting and verification system, ensuring the comparability and auditability of cross-border process data would be practically impossible. This reveals a profound shift in the nature of trade governance: digitalization is no longer just an "optional promotional tool" for green policy but is evolving into a "mandatory prerequisite" for market access.

Table 2: The Environmental Footprint of Digitalization: A Statistical Snapshot

Impact Dimension	**Key Metrics and Data**	**Main Impact and Paradox**
Energy Consumption	Global data center electricity demand could surge from ~460 TWh in 2022 to over 1,000 TWh by 2026, driven largely by AI. This is roughly equivalent to the annual electricity consumption of Japan. (Source: IEA, 2024)	Creates a paradox of "using the non-green of digitalization to pursue the green of trade." If new power demand is met by fossil fuels, digitalization itself becomes a barrier to global emissions reduction.
E-waste	62 million tonnes of e-waste were generated globally in 2022, with a documented formal collection and recycling rate of only 22.3%. E-waste generation is growing five times faster than recycling. (Source: UNITAR & ITU, 2024 6)	The environmental burden is disproportionately shifted from major consumers of digital technology to developing countries that process its waste, exacerbating global environmental injustice.
Critical Minerals	To meet the demands of the clean energy transition, production of minerals like graphite, lithium, and cobalt may need to increase by nearly 500% by 2050 relative to 2018 levels. (Source: World Bank, 2020 8)	The digital and green transitions are highly dependent on the same set of critical minerals, intensifying international geopolitical competition over these strategic resources.

Note: Data is compiled from the latest available reports. Energy consumption projections are scenario-dependent and reflect the IEA's base case. E-waste figures represent documented formal recycling; informal and illegal flows are not fully captured. Mineral demand projections are based on a below 2°C climate scenario.

4 The "Double-Edged Sword" Effect: Deconstructing the Risks and Paradoxes of the Digital-Green Transition

Viewing digitalization as a panacea for environmental problems is a dangerous oversimplification. In fact, the digitalization process itself has a significant "double-edged sword" effect. Its own negative environmental impacts, the economic paradoxes it may trigger, and the risk of exacerbating social inequality collectively pose major challenges to achieving a sustainable transformation. A critical examination of these countervailing forces is essential for a balanced understanding and for the formulation of effective policy.

4.1 The Materiality of the Virtual: The Environmental Footprint of Digitalization

The digital economy may seem “intangible” and “weightless,” but its physical foundation—composed of data centers, communication networks, and billions of end-user devices—has a massive and rapidly growing environmental footprint. This material reality creates a central paradox where the tools of sustainability are themselves significant drivers of environmental degradation. The main impacts can be categorized into three critical areas: energy consumption, electronic waste, and the demand for critical minerals, as summarized in Table 2.

The surge in energy consumption is particularly alarming. The International Energy Agency (IEA) reports that after consuming an estimated 460 terawatt-hours (TWh) in 2022, data centers' total electricity consumption could reach more than 1,000 TWh in 2026, with AI being the most important driver of this growth.5 This raises a critical question about the source of this new energy. If the increasing energy demand is met by fossil fuels, digitalization could paradoxically become a barrier to global emissions reduction efforts. This is not a hypothetical risk; the IEA notes that currently, fossil fuels provide nearly 60% of the power to data centers globally, with coal being the single largest source due to the concentration of facilities in regions like China. The immediate and immense need for reliable, 24/7 power for data centers creates a temporal mismatch with the deployment of low-carbon energy sources. While emerging technologies like small modular nuclear reactors (SMRs) are potential long-term solutions, the urgent demand in the short term is more likely to be met by readily available and scalable sources like natural gas.11 This could trigger a new wave of investment in fossil fuel infrastructure, creating a “carbon lock-in” that would undermine the very climate goals the green transition aims to achieve. Electronic waste (e-waste) represents another severe environmental challenge. The Global E-waste Monitor 2024 reveals a staggering crisis: a record 62 million tonnes of e-waste were generated in 2022, yet only 22.3% was documented as properly collected and recycled.6 Alarmingly, the generation of e-waste is rising five times faster than documented recycling efforts, indicating a systemic failure of the circular economy model for electronics.6 This problem is compounded by issues of global injustice, as large volumes of e-waste are illegally exported from developed to developing countries, where informal and hazardous recycling methods release toxic substances like mercury and lead into the environment, harming local communities. Finally, the digital and green transitions are locked in a fierce competition for the same pool of critical minerals. The World Bank projects that the production of minerals such as graphite, lithium, and cobalt may need to increase by nearly 500% by 2050 to meet the demand for clean energy technologies like batteries and wind turbines.8 However, these same minerals are also essential components of digital hardware, including smartphones, laptops, and servers.15 This creates a direct resource conflict between the two transitions. In the short-to-medium term, a zero-sum dynamic may emerge where the minerals used to build a new AI data center are minerals that cannot be used to manufacture electric vehicle batteries. This internal contradiction intensifies geopolitical competition over resource-rich regions and threatens to create supply chain bottlenecks that could slow down both the digital and green transformations.

4.2 The Efficiency Paradox: Confronting the “Rebound Effect” in the Digital Age

According to the economic theory of the “rebound effect,” also known as “Jevons' Paradox,” improvements in resource use efficiency driven by technological progress can paradoxically lead to an increase in the overall consumption of that resource. By lowering the effective price of a service (e.g., making travel cheaper through a more fuel-efficient engine), technology can stimulate more demand, potentially offsetting or even negating the initial efficiency gains. In extreme cases, a “backfire” phenomenon can occur where total resource consumption actually increases. The digital age is rife with examples of this paradox. While e-commerce logistics may reduce carbon footprints on a per-unit basis through optimized delivery routes, the sheer convenience and low cost of online shopping have greatly stimulated overall consumption frequency and volume. This leads to a sharp increase in the total number of parcels shipped, a surge in packaging waste, and a significant environmental impact from "free" returns logistics. The net result may be a negative environmental outcome, despite the efficiency gains in the logistics of a single purchase. This 'backfire' exemplifies the rebound effect where technological efficiency gains do not necessarily lead to a decrease in overall resource consumption. This paradox reveals a fundamental contradiction at the heart of many techno-optimistic narratives: without corresponding demand-side constraints, behavioral changes, and price signals that reflect true environmental costs, efficiency improvements alone may achieve relative decoupling (less impact per unit of GDP) but will struggle to achieve the absolute decoupling (a total reduction in resource use) necessary for true sustainability.

4.3 New Geoeconomic Fault Lines: The Superposition of the Digital Divide and Green Barriers

While often hailed as an "equalizer" with the potential to foster inclusive development, digital technology can also act as a powerful "amplifier" of inequality due to its uneven global distribution and application. When the inherent digital divide combines with the rise of new, complex green trade barriers, a composite and exclusionary risk emerges that is particularly detrimental to developing countries. This paper terms this phenomenon "stacked barriers." The stacked barriers created by the combination of the digital divide and green trade regulations could exacerbate global inequalities. Developing country exporters, already at a disadvantage in the digital economy, are now burdened with additional costs and technological requirements to comply with complex green trade regulations. The logic is as follows: exporters from developing countries must now not only meet the stringent physical environmental standards of importing countries (the traditional green barrier) but must also possess the costly digital technology and capabilities to collect, manage, and submit verifiable data to prove their compliance (the emerging digital barrier). Consider the example of a cocoa farmer in West Africa who uses sustainable, agroforestry-based farming methods. Under new EU regulations aimed at preventing deforestation, this farmer's product might be perfectly compliant in substance. However, if they cannot afford or access the Geographic Information System (GIS) and blockchain-based traceability platform required to prove that their cocoa does not come from a recently deforessted area, their product may be barred from the EU market. In this scenario, the lack of digital capacity becomes a de facto non-tariff barrier to trade, punishing a producer who is environmentally responsible but digitally disadvantaged. This is not a distant threat; UNCTAD data shows that core digital infrastructure in developing nations is severely underfunded, and foreign direct investment in the digital economy is highly concentrated in a handful of middle-income countries, leaving the least developed countries far behind.4 Thus, a worrying prospect emerges: instead of helping developing countries integrate into the global green economy, digitalization, when combined with stringent green regulations, could become a new, higher barrier that deepens global trade inequality and creates new geoeconomic fault lines between the digital haves and have-nots. This dynamic helps to reconcile what might otherwise appear as contradictory narratives from major international organizations. The WTO's optimistic forecast that AI will boost aggregate global trade is a macro-level view that captures the overall efficiency gains. However, UNCTAD's analysis of the deepening digital divide provides a crucial micro-level, bottom-up perspective. The concept of "stacked barriers" provides the theoretical bridge between these two views, explaining how both can be simultaneously true. The aggregate trade gains predicted by the WTO will likely be captured disproportionately by digitally advanced firms and economies that can easily meet the new digital-green compliance requirements. Meanwhile, the costs and barriers will be borne by the digitally disadvantaged, leading to a world of greater aggregate trade but also greater inequality.

5 The Geopolitics of Transition: Global Governance and Policy Paths

Faced with the immense opportunities and severe challenges of the digital-driven green trade transformation, establishing a coordinated and inclusive global governance framework is imperative. The current landscape, however, is characterized not by cooperation but by intensifying competition, as major economic powers pursue divergent strategies, threatening to fragment the global trading system.

5.1 A Three-Way Game: A Comparative Analysis of EU, China, and US Strategic Paths

The governance of global digital-green trade is developing in a multi-centric and differentiated manner. The world's three largest economic blocs—the European Union, China, and the United States—are each choosing distinct policy paths based on their unique economic structures, technological advantages, and strategic considerations. These competing approaches are creating a complex geopolitical dynamic with significant implications for global trade rules and for developing countries caught in the middle. Table 3 provides a comparative overview of these strategic paths (Table 3).

Table 3: EU-China-US Digital Green Trade Path Comparison Matrix

Comparison Dimension	**European Union (EU)**	**China**	**United States (USA)**
Strategic Framework	European Green Deal	Dual Carbon Strategy, Digital China	Green Trade Strategy
Core Path	Rule-driven	Industry-driven	Market-driven
Signature Tools	CBAM, Digital Product Passport	Industrial policy, pilot zones	Incentives, enforcement, innovation
Role of Digitalization	Mandatory compliance tool	Core development engine	Market-enabling factor
Impact on Developing Countries	High-standard barriers, compliance costs	Infrastructure/standard exports	Capacity building, enforcement cooperation

Source: Compiled from the European Commission's "European Green Deal", China's "14th Five-Year Plan" and "Dual Carbon" top-level documents, the U.S. Customs and Border Protection's "Green Trade Strategy", and related official materials.

The European Union has adopted a rule-driven approach, seeking to leverage its significant market power to set global standards for sustainability. The European Green Deal serves as its overarching strategic framework, with policies like CBAM and the Digital Product Passport acting as its signature tools. For the EU, digitalization is primarily a mandatory compliance tool—an essential piece of infrastructure for enforcing its ambitious environmental regulations and ensuring the traceability of supply chains. The impact on developing countries is a double-edged sword: while promoting higher environmental standards, this approach also imposes significant compliance costs and creates the "stacked barriers" discussed previously. China, in contrast, is pursuing an industry-driven path. Guided by its "Dual Carbon" strategy and "Digital China" vision, Beijing views the digital-green nexus as a core engine for economic development and technological leadership. Its approach relies heavily on industrial policy, state-led investment in green technologies and digital infrastructure, and the establishment of pilot zones to test new models. For China, digitalization is a fundamental development engine, not just a regulatory tool. Its global impact is often felt through the export of its digital infrastructure and technical standards via initiatives like the Belt and Road Initiative, which offers developing countries an alternative model to the EU's regulatory-heavy approach. The United States has historically favored a market-driven strategy. While the U.S. has recently become more active with its "Green Trade Strategy," its approach primarily relies on market incentives (like the tax credits in the Inflation Reduction Act), trade enforcement actions against environmental violations, and fostering private-sector innovation. In the U.S. model, digitalization is seen as a market-enabling factor that helps companies innovate and compete more effectively. Its engagement with developing countries often focuses on capacity building and cooperation on trade enforcement, representing a less prescriptive approach than the EU's but also a less state-directed one than China's. This three-way competition brings both innovative momentum and a significant risk of regulatory conflict and fragmentation, which could raise costs and create uncertainty for global businesses.

5.2 Charting a Collaborative Future: Policy Recommendations for an Inclusive Governance Architecture

Given the complexity of the transition and the differing paths of major economies, an effective global governance framework must be built on the principles of multilateralism, policy coordination, and inclusive development. A fragmented, go-it-alone approach risks undermining the very goals of the digital-green transition. At the national level, governments must break down policy silos that separate digital, environmental, and trade ministries. Coordinated "Twin Transition" national strategies are needed to ensure that environmental impacts are a central consideration in the planning of digital infrastructure and that digital tools are effectively leveraged to meet climate targets. This integrated approach can help mitigate the "double-edged sword" effects domestically before they spill over into the international arena. At the international level, strengthening multilateral cooperation is paramount. First, within frameworks like the WTO and OECD, member states should actively promote the development of internationally recognized and interoperable standards for digital carbon footprint accounting and verification. Harmonized standards are essential to prevent a patchwork of conflicting regulations that would stifle trade. Second, the "Aid for Trade" mechanism should be reformed and strengthened to specifically focus on supporting developing countries in building their digital infrastructure and enhancing their capacity to comply with new digital and green standards. This is critical to mitigating the risk of "stacked barriers." Finally, the fairness of trade rules must be upheld. Unilateral measures like CBAM should be subject to robust multilateral review to ensure they are non-discriminatory and do not constitute disguised protectionism. The WTO's principle of "Special and Differential Treatment" should be meaningfully applied, providing developing countries with adequate transition periods and technical support to adapt to new requirements. Recent discussions within the WTO about the need for reform to better serve the interests of developing countries make this a particularly opportune moment for such an agenda.18 At the corporate and societal level, public-private partnerships should be vigorously promoted to co-create practical standards and solutions. Governments can provide the regulatory framework, but the private sector possesses the technological expertise and operational knowledge to implement these standards effectively. Clear guidance should be provided to exporting enterprises, particularly SMEs, on how to navigate the new compliance landscape. A practical approach, such as the "Minimum Viable Product (MVP) for Compliance Data" outlined in Box 2, can help firms focus their efforts on the most critical data points required for market access.

6 Conclusion and Future Research Prospects

6.1 Main Research Conclusions

This study has systematically explored the intrinsic mechanisms, complex effects, and governance paths of the digital-driven green trade transformation, leading to the following core conclusions:

First, digital technology drives the profound transformation of green trade not through a single, linear path but through a systemic and interconnected "Trilogy" of three core mechanisms. These are: empowering green innovation at the production end, rebuilding trust through transparency in the distribution process, and creating a positive feedback loop of demand and regulation at the market and governance end.

This integrated framework demonstrates that digitalization is a systemic catalyst, fundamentally reshaping the entire trade ecosystem.

Second, this transformation process exhibits a significant “double-edged sword” effect, creating profound paradoxes that challenge simplistic, techno-optimistic narratives. The massive and growing environmental footprint of digital infrastructure itself (in terms of energy, e-waste, and minerals), the economic “rebound effect” that may be triggered by efficiency gains, and the risk of “stacked barriers” formed by the superposition of the digital divide and green barriers are the three core constraints to achieving a truly sustainable transition. These challenges indicate that without careful governance, digitalization could undermine the very sustainability it aims to promote.

Third, global digital-green trade governance is not converging toward a single model but is instead showing a multi-centric, differentiated, and competitive landscape. The EU, China, and the US have adopted distinct policy paths characterized by “rule-driven,” “industry-driven,” and “market-driven” approaches, respectively. While this competition can spur innovation, it also brings a significant risk of regulatory conflict, market fragmentation, and increased compliance burdens on developing nations, urgently necessitating the construction of a coordinated and inclusive multilateral governance framework.

6.2 Limitations and Future Prospects

As a theoretical and exploratory work, this study has certain limitations that open avenues for future research. First, its analysis is primarily based on the construction of a theoretical framework and qualitative analysis of policy trends and secondary data. It lacks quantitative empirical testing with large-scale, cross-national data, which would be necessary to validate the causal strength of the proposed mechanisms. Second, the study treats “digital technology” as a relatively homogenous category. The heterogeneous effects of different types of digital technologies (e.g., AI versus blockchain) across various industries (e.g., agriculture versus electronics) need further granular exploration.

Based on these limitations, future research could proceed in the following directions: Quantitative Empirical Testing: Researchers could construct composite indices to measure countries’ digital technology levels and green trade development. Using cross-national panel data, econometric models could be employed to empirically test the strength and significance of the three transmission mechanisms proposed in this paper, as well as to quantify the impact of the “stacked barriers” on the trade performance of developing countries.

In-depth Industry Case Studies: Future work could select representative industries that are at the forefront of the digital-green transition, such as fast fashion, electronics, or automotive sectors. In-depth case studies of these industries could reveal the practical operational details, real-world obstacles, and corporate strategies involved in leveraging digital technology for green trade, providing a much-needed ground-level perspective to complement this paper’s macro-level analysis.

Research on International Rule-Making and Impact: A critical area for future inquiry is the political economy of emerging digital-green trade rules like CBAM and the Digital Product Passport. Using theories and methods from international relations and international political economy, scholars could study the formulation processes of these rules, the strategic interactions among key state and non-state actors, and their long-term geoeconomic impacts on the structure of global value chains, North-South relations, and the future of the multilateral trading system.

Author Biography FAN Chi, male, born in December 1988 in Zhalantun City, Inner Mongolia, is an Associate Professor and Master’ s Supervisor at the School of Business, Qilu University of Technology. His research focuses on enterprise digital transformation. Correspondence Address: No. 3028 Jingshi East Road, Jinan, Shandong Province, 250200, China. Email: 274721328@qq.com, ORCID:

https://orcid.org/0009-0007-2784-945X.

References

[1] World Trade Organization. (2025). *World Trade Report 2025*. WTO.

[2] UNCTAD. (2024). *Digital Economy Report 2024: Shaping an environmentally sustainable and inclusive digital future*. United Nations.

[3] OECD. (2025). *Recommendation of the Council on Digital Technologies and the Environment*. OECD Publishing.

[4] Can, M., Ahmed, Z., & Ahmad, M. (2022). Can green trade save the environment? The role of green trade openness in the era of environmental degradation. *Environmental Science and Pollution Research, 29*, 83938 83948.

[5] Muratoğlu, G. (2022). *Exploring the Impact of Trading Green Products on the Environment: Introducing the Green Openness Index*. MPRA Paper No. 106730.

[6] UNCTAD. (2021). *A European Union Carbon Border Adjustment Mechanism: Implications for developing countries*. United Nations.

[7] Yildiz, A. K., & Tanyeri, U. (2025). Blockchain-Enabled Supply Chain Management: A Review of Security, Traceability, and Data Integrity Amid the Evolving Systemic Demand. *Applied Sciences, 15*(9), 5168.

[8] European Commission. (2022). *Proposal for a Regulation on Ecodesign for Sustainable Products*. COM(2022) 142 final.

[9] Banque de France. (2020). CO2 emissions embodied in international trade. *Bulletin de la Banque de France, 228*(1).

[10] European Commission. (2023). *Commission Implementing Regulation (EU) 2023/1773*. Official Journal of the European Union.

[11] International Energy Agency. (2025). *Energy and AI*. IEA.

[12] UNITAR & ITU. (2024). *Global E-waste Monitor 2024*. United Nations.

[13] World Bank. (2020). *Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition*. World Bank Group.

[14] Sorrell, S. (2009). Jevons' Paradox revisited: The evidence for backfire from improved energy efficiency. *Energy Policy, 37*(4), 1456-1469.

[15] European Commission. (2019). *The European Green Deal*. COM(2019) 640 final.

[16] The State Council of the People's Republic of China. (2022). *14th Five-Year Plan for the Development of the Digital Economy*.

[17] U.S. Customs and Border Protection. (2022). *Green Trade Strategy*.

[18] Tipping, A., & Byrde, A. (2021). *Greening Aid for Trade: A focus on LDCs and SIDS*. Friedrich-Ebert-Stiftung.

[19] World Bank. (2001). *The Role of Special Differential Treatment for Developing Countries in GATT and the World Trade Organization*. Open Knowledge Repository.

[20] AI may boost global trade by nearly 40 per cent in 15 yrs: Report, https://timesofindia.indiatimes.com/business/international-business/ai-may-boost-global-trade-by-nearly-40-per-cent-in-15-yrs-report/articleshow/123963448.cms

[21] World Trade Report 2025: trade and artificial intelligence - YouTube, https://www.youtube.com/watch?v=WcPl9tbEhco

[22] Global investment in the digital economy surges but remains uneven - UNCTAD, https://unctad.org/news/global-investment-digital-economy-surges-remains-uneven

[23] Executive summary Electricity 2024 Analysis - IEA, https://www.iea.org/reports/electricity-2024/executive-summary

[24] The global E-waste Monitor 2024 Electronic Waste Rising Five Times Faster than Documented E-waste Recycling: UN, https://ewastemonitor.info/the-global-e-waste-monitor-2024/
[25] The Global E-waste Monitor 2024 - ITU, https://www.itu.int/en/ITU-D/Environment/Pages/Publications/The-Global-E-waste-Monitor-2024.aspx
[26] Climate-Smart Mining: Minerals for Climate Action - World Bank, https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action
[27] Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition, https://commdev.org/publications/minerals-for-climate-action-the-mineral-intensity-of-the-clean-energy-transition/
[28] AI: Five charts that put data-centre energy use and emissions into context - Carbon Brief, https://www.carbonbrief.org/ai-five-charts-that-put-data-centre-energy-use-and-emissions-into-context/
[29] Energy and AI - NET, https://iea.blob.core.windows.net/assets/601eaec9-ba91-4623-819b-4ded331ec9e8/EnergyandAI.pdf
[30] AI and energy: an IEA perspective - Modern Power Systems, https://www.modernpowersystems.com/analysis/data-centres/ai-and-energy-an-iea-perspective/
[31] Global E-Waste Monitor 2024 - CEP - Circular Electronics Partnership, https://cep2030.org/resource/global-e-waste-monitor-2024/
[32] Global e-Waste Monitor 2024: Electronic Waste Rising Five Times Faster than Documented E-waste Recycling | UNITAR, https://unitar.org/about/news-stories/press/global-e-waste-monitor-2024-electronic-waste-rising-five-times-faster-documented-e-waste-recycling
[33] Critical Minerals - Energy System - IEA, https://www.iea.org/energy-system/industry/critical-minerals
[34] Critical Minerals Topics - IEA, https://www.iea.org/topics/critical-minerals
[35] Digital Economy Report 2024 | UN Trade and Development (UNCTAD), https://unctad.org/publication/digital-economy-report-2024
[36] Global trade at crossroads: Panel calls for WTO reform, https://m.economictimes.com/news/economy/foreign-trade/global-trade-at-crossroads-panel-calls-for-wto-reform/articleshow/124013438.cms
[37] 'Pivotal moment': China ends special treatment in future talks; WTO welcomes move for fairer global trade, https://timesofindia.indiatimes.com/business/international-business/pivotal-moment-china-ends-special-treatment-in-future-talks-wto-welcomes-move-for-fairer-global-trade/articleshow/124093017.cms

To Cite This Article Chi FAN(2025). Digital Leviathan or Green Catalyst? Deconstructing the Mechanisms, Paradoxes, and Governance of the Global Green Trade Transformation. *Do Business and Trade Facilitation Journal*, *5*(1), 14–26. https://doi.org/10.6914/dbtf.050102