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Sustainability in E-Commerce: The Importance of Transparency in the Supply Chain

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Abstract

The rapid expansion of e-commerce has reshaped global consumption systems by transforming production processes, logistics infrastructures, and consumer behaviour. While this transformation has generated significant economic opportunities, it has simultaneously intensified environmental pressures, particularly through last-mile delivery emissions, excessive packaging waste, and high return rates. At the same time, the growing diffusion of corporate sustainability reporting has raised increasing concerns about greenwashing, defined as the misrepresentation of environmental performance through selective disclosure or symbolic communication. This study aims to provide a comprehensive assessment of sustainability practices in e-commerce, focusing on the relationship between environmental performance, transparency, and economic outcomes. Particular attention is devoted to the role of blockchain technology as a potential mechanism for enhancing verifiable transparency in complex supply chains. The research adopts a multiple case study design grounded in the methodological frameworks and integrates qualitative analysis with a semi-quantitative evaluation model. Seven companies operating in different segments of the e-commerce ecosystem are analyzed through an extensive review of secondary data sources, including ESG reports, financial disclosures, NGO assessments, and industry benchmarks. The findings reveal a substantial gap between declared sustainability commitments and actual implementation, with significant heterogeneity across firms. Companies that embed sustainability into their strategic core demonstrate stronger alignment between environmental and economic performance, whereas firms relying primarily on communication-driven approaches exhibit higher implementation gaps. The study contributes to the literature by introducing an analytical framework centered on the concept of the implementation gap and by demonstrating the central role of transparency in determining sustainability effectiveness. It also highlights the potential, yet still largely unrealized, role of blockchain technology in addressing information asymmetry and reducing greenwashing in e-commerce.

Keywords: e-commerce; sustainability; blockchain; ESG; greenwashing; supply chain traceability

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1. Introduction

The expansion of e-commerce represents one of the most significant structural transformations of the global economy in recent decades. Digital platforms have enabled firms to transcend geographical barriers, optimize transaction processes, and scale operations

at an unprecedented pace. This transformation has been driven by technological innovation, changes in consumer preferences, and the increasing integration of global value chains. However, alongside these benefits, e-commerce has introduced new and complex sustainability challenges that require systematic investigation.

As discussed in the underlying research material, the environmental impact of e-commerce is closely linked to its logistics architecture. The growth of last-mile delivery services has led to increased urban congestion and higher levels of greenhouse gas emissions, particularly in densely populated areas. This issue is further exacerbated by consumer demand for rapid delivery, which reduces opportunities for logistical optimization and increases the frequency of partially loaded shipments.

Another critical dimension concerns packaging practices. The need to protect goods during transport has led to the widespread use of single-use materials, often exceeding functional requirements. This has contributed to the accumulation of waste and raised concerns about resource efficiency. Moreover, the high rate of product returns in e-commerce, particularly in sectors such as apparel, introduces additional environmental burdens through reverse logistics processes, including transportation, repackaging, and, in some cases, disposal.

In response to these challenges, firms have increasingly adopted sustainability strategies and expanded their ESG reporting [1,2]. However, the proliferation of sustainability claims has not always been matched by substantive action. This discrepancy has led to growing concerns about greenwashing, which undermines stakeholder trust and reduces the effectiveness of sustainability initiatives. Not every "implementation gap" can be considered greenwashing. Unfortunately, sometimes it is due to operational constraints such as a lack of organizational resources and of the ability to reach their plans. Therefore, it is necessary to differentiate between willingness and lack of resources and capacity. The former involves the deliberate dissemination of misleading information to create a positive environmental reputation and gain a competitive advantage. The latter refers to the incapacity to develop a sustainability plan due to objective limitations.

Beyond its operational role, transparency should be understood as an enabling mediator between sustainability practices and stakeholder trust. Existing studies often treat transparency primarily as a reporting mechanism through which firms communicate ESG information. This perspective, while important, risks overlooking its broader theoretical function. Transparency can actively shape organizational behavior by increasing the verifiability of sustainability commitments, reducing information asymmetries, and creating stronger incentives for firms to align their actions with their public claims. From this perspective, transparency is not merely an outcome of sustainability efforts but a mechanism that facilitates the effective translation of sustainability strategies into credible stakeholder value. Focusing on transparency as an enabling mediator therefore offers a novel theoretical lens for understanding how sustainability initiatives generate legitimacy and trust in e-commerce environments. This approach also provides a stronger academic foundation for examining technologies such as blockchain, whose primary contribution lies not simply in improving disclosure, but in strengthening the credibility and governance processes that connect sustainability performance with stakeholder perceptions.

The present study addresses this issue by examining the relationship between sustainability practices and transparency in e-commerce. It seeks to determine whether firms are genuinely integrating sustainability into their operations or merely using it as a reputational tool. In addition, it explores the potential role of blockchain technology in enhancing the credibility of sustainability claims by enabling verifiable transparency across supply chains [3,4].

2. Literature Review

The literature on sustainability in e-commerce is characterized by a convergence of multiple theoretical perspectives, reflecting the complexity of the phenomenon. One of the foundational frameworks is the Triple Bottom Line, which conceptualizes sustainability as the integration of economic, environmental, and social objectives [5]. This approach has been instrumental in broadening the scope of corporate performance beyond purely financial metrics, emphasizing the importance of long-term value creation [6].

However, the implementation of sustainability principles varies significantly across firms [7]. While some organizations adopt a proactive approach, embedding sustainability into their core strategy, others engage in more superficial practices aimed primarily at enhancing their public image. This divergence has been widely documented in the literature and is often associated with differences in governance structures, stakeholder pressures, and organizational culture [8].

The measurement of sustainability performance remains a critical challenge. ESG metrics have gained prominence as a standardized framework, yet they are subject to several limitations [9]. The absence of universally accepted standards and the reliance on self-reported data introduce inconsistencies and reduce comparability [10]. These issues are particularly relevant in the context of e-commerce, where supply chains are often complex and geographically dispersed [11].

Environmental studies on e-commerce highlight the dual nature of its impact. On one hand, digitalization can reduce certain environmental burdens associated with physical retail, such as energy consumption in stores. On the other hand, it introduces new challenges related to logistics, packaging, and consumption patterns. The net effect of these opposing forces remains a subject of ongoing debate [12].

The concept of greenwashing has emerged as a central theme in sustainability research. It reflects the tendency of firms to present an exaggerated or misleading image of their environmental performance [13]. This phenomenon is closely linked to information asymmetry, which limits the ability of stakeholders to verify corporate claims. As a result, there is a growing need for mechanisms that can enhance transparency and accountability.

Blockchain technology has been proposed as one such mechanism. By providing a decentralized and immutable record of transactions, blockchain can reduce information asymmetry and improve traceability [14,15]. Its application in supply chains has attracted considerable attention, particularly in sectors characterized by complex and opaque networks [16]. Despite its potential, however, the adoption of blockchain remains limited, and its practical implications for sustainability are not yet fully understood [17].

A review of the existing literature reveals three important gaps that motivate the present study. First, although prior research has extensively discussed sustainability strategies in e-commerce, there is limited evidence regarding how companies actually implement these practices in their daily operations. Much of the literature focuses on sustainability commitments, reporting frameworks, or ESG disclosures, while providing less insight into the organizational processes through which such initiatives are translated into practice. This gap directly motivates RQ1, which investigates how e-commerce companies implement sustainability practices.

Second, existing studies have repeatedly highlighted the risk of greenwashing, yet relatively few have systematically compared corporate sustainability claims with observable implementation outcomes. As a consequence, there remains insufficient understanding of the extent to which publicly communicated commitments correspond to actual organizational behavior. This unresolved debate provides the foundation for RQ2, which examines the gap between sustainability commitments and implementation.

Third, while blockchain is frequently presented as a promising tool for improving transparency and traceability, the literature remains largely conceptual. Current research offers limited empirical evidence on whether blockchain can effectively mitigate greenwashing by strengthening the verification of sustainability claims and reducing information asymmetries across supply chains. Moreover, scholars have not reached a consensus regarding the conditions under which blockchain generates meaningful governance and accountability benefits. This gap motivates RQ3, which explores how blockchain can improve transparency and reduce greenwashing.

Taken together, these gaps suggest the need for a research design capable of examining sustainability practices, implementation outcomes, and transparency mechanisms in their organizational context. A comparative case study approach is particularly suitable because it enables the systematic comparison of different e-commerce companies, allowing similarities and differences in sustainability strategies, implementation processes, and transparency practices to be identified. Furthermore, comparative cases provide an appropriate setting for assessing whether blockchain-based solutions contribute to reducing the discrepancy between sustainability claims and actual performance. The three research questions therefore emerge directly from the literature and collectively address a significant gap in current knowledge regarding the role of blockchain-enabled transparency in mitigating greenwashing.

This study addresses the following research questions:

RQ1: How do e-commerce companies implement sustainability practices?
RQ2: What is the gap between sustainability commitments and actual implementation?
RQ3: How can blockchain improve transparency and reduce greenwashing?

3. Materials and Methods

3.1. Research Design

The research employs a multiple case study design, which is well-suited for analyzing complex and context-dependent phenomena. This approach allows for an in-depth examination of individual cases while enabling cross-case comparison and pattern identification. The methodological framework follows the principles articulated by Eisenhardt and Yin, combining inductive and deductive elements to generate theoretically grounded insights.

3.2. Cases Selection Strategy

To provide an empirical basis for the previous theoretical discussion, a comparative study was conducted on seven selected e-commerce companies: Shopify Inc., Ottawa, ON, Canada, Patagonia Inc., Ventura, CA, USA, Allbirds Inc., San Francisco, CA, USA, Vinted UAB, Vilnius, Lithuania, H&M AB, Stockholm, Sweden, Zalando SE, Berlin, Germany, and Amazon.com Inc., Seattle, WA, USA. The companies were chosen to capture a wide range of business models, geographies, and sustainability strategies. The selection of cases follows a purposive sampling strategy designed to capture variation across key dimensions while maintaining a sufficient degree of comparability. These dimensions include firm size, market positioning, business model characteristics, and degree of sustainability integration.

To minimize selection bias and ensure consistency across cases, a set of formal inclusion criteria was applied. First, all selected companies operate at a significant scale within the e-commerce ecosystem and have an established international or regional market presence. Second, each company publicly communicates sustainability commitments through sustainability reports, ESG disclosures, annual reports, or equivalent corporate documentation, making it possible to compare stated commitments with observable practices. Third, the selected firms represent different but influential e-commerce models, including platform-based marketplaces (Amazon, Shopify, Zalando), direct-to-consumer

sustainability-oriented brands (Patagonia and Allbirds), traditional retailers with strong digital operations (H&M), and circular economy platforms (Vinted). This variation enables the study to examine whether the relationship between sustainability, transparency, and greenwashing differs across business models.

At the same time, several exclusion criteria were adopted. Smaller firms, companies with limited public disclosure, and organizations lacking sufficiently documented sustainability initiatives were excluded because they would not allow a systematic assessment of implementation practices or transparency mechanisms. Similarly, firms operating primarily outside the e-commerce environment were not considered.

The choice of these seven cases therefore reflects a balance between diversity and comparability. Although the firms differ in their operational models, they share common characteristics that are central to the research objectives: substantial market relevance, broad geographical reach, active engagement with sustainability reporting, and exposure to stakeholder scrutiny regarding environmental claims. These common boundaries provide a suitable basis for comparative analysis while allowing the study to explore how different organizational contexts influence the implementation of sustainability practices and the potential role of blockchain in reducing greenwashing.

3.3. Data Collection and Triangulation

A multi-source data collection process was employed in 2025 to provide maximum credibility and validity to the comparative study. Formal reports and disclosures, primarily the companies' own sustainability reports and websites, were the primary data source for all the companies. Among them, annual sustainability or impact reports, press releases of different sustainability initiatives, and special company website pages listing environmental and social responsibility initiatives have been included. Each of these sources gave the most direct access to the reported goals, measurements, and stories of sustainability of each company.

But one of the acknowledged drawbacks of sole reliance on company self-reporting is that there can be bias or selectivity. As compensation for this and to counter unthinking acceptance of corporate sources, the research made use of a broad variety of third-party and independent sources of information. These include:

- Industry and NGO reports: Greenpeace and Stand.earth, for instance, released investigative reports into e-commerce companies' carbon footprint and packaging and used them to cross-check and put into perspective the companies' asserted statements [18]. Industry and NGO reports generally point out gaps of promise and performance, and these constituted an independent cross-check of realities such as emission rates and renewable energy deployment. Examples included the Fashion Transparency Index and reports by such bodies as the Sustainable Apparel Coalition that involved companies such as Zalando and H&M.
- ESG rating agencies and databases: Environmental and social rating agency ratings and sustainability indexes were taken into account. Quotations from databases like Carbon Disclosure Project (CDP scores), MSCI ESG ratings, and B Corporation certifications were used wherever feasible. Being a B Corp certified company or listed in sustainability indexes was a second tier of verification of their reputation for Allbirds and Patagonia. For Amazon, outside ratings or lack of them (it famously flunked by CDP on transparency) appeared to be a criticism [19].
- Scholar and news sources: Scholarly writing was used most extensively to define terms like greenwashing, reporting guidelines, and sustainability plan [19,20]. Case studies and news media sources were used to make events current like lawsuits/scandals in 2023 against H&M's marketing strategies [21], or Patagonia's plan to shift ownership

to an environmental trust [22]. They were used to make the analysis current and to incorporate criticism not found in annual reports.

- Surveys and statistics of consumers: Surveys of second-hand usage on second-hand platforms and/or such usage statistics of the organization or academia to the public were conducted for Vinted to measure the effect of its model [23]. Likewise, recent statistics of Shopify's merchants and those using Shopify's sustainability tools put context into the platform's scope [24].

By triangulating data from company sources with independent sources, the research attempted to create a more balanced picture of each company's record on sustainability. Through this process, the need to rely upon potentially one-sided company reports is obviated, because independent corroboration and criticism are better at identifying what is left out of company reports. For instance, if a company had reported to be "carbon neutral" in its activities, external sources were utilized to determine what that means (i.e., deployment of offsets rather than a decrease in actual emissions) and whether there has been a controversy surrounding that statement. This multi-source technique strengthens the validity of the comparison because conclusions are not drawn from a single source [25]. Where data from various sources disagreed, that in turn became a subject of the analysis—frequently illustrating the finer points along which sustainability is measured or greenwashing occurs. Overall, the integration of internal and external information, qualitative reportage and quantitative data, peer literature and industry literature on sustainability creates an appropriate setting within which to evaluate and compare the sustainability initiatives of e-commerce firms.

3.4. Analytical Framework

To increase analytical rigor, the study employs a structured evaluation framework that assesses sustainability performance across three dimensions: environmental performance, transparency, and social responsibility. Each dimension is operationalized through a set of indicators derived from the literature and adapted to the specific context of e-commerce.

3.5. Semi-Quantitative Scoring Model

To facilitate systematic comparison across cases, the study adopts a semi-quantitative scoring model that translates qualitative evidence into standardized numerical values. The model is based on the analytical framework presented in Section 3.4 and evaluates each company across three dimensions: Environmental Performance (EP), Transparency Index (TI), and Social Responsibility (SR).

Each dimension is assessed using multiple indicators derived from the sustainability, ESG, and supply-chain transparency literature. The coding process relies on evidence collected through data triangulation, including corporate sustainability reports, ESG disclosures, NGO assessments, certification records, academic studies, and independent media investigations. To improve consistency, all indicators were evaluated using the same three-point scale.

Score 1 (Low) was assigned when evidence suggested limited implementation, absence of measurable targets, weak disclosure practices, lack of independent verification, or the presence of significant controversies and implementation gaps.

Score 2 (Medium) was assigned when firms demonstrated partial implementation of sustainability initiatives, disclosed relevant information, and reported measurable progress, but with incomplete coverage, limited verification mechanisms, or inconsistencies between commitments and observed outcomes.

Score 3 (High) was assigned when firms demonstrated extensive implementation of sustainability practices, transparent and comprehensive reporting, externally verified

disclosures, measurable performance improvements, and strong alignment between sustainability commitments and operational practices.

Environmental Performance (EP) was evaluated through carbon emissions management, renewable energy adoption, packaging efficiency, circular economy initiatives, and reverse logistics practices. Transparency Index (TI) was assessed through ESG disclosure quality, supply-chain traceability, third-party verification, and accessibility of sustainability information. Social Responsibility (SR) was evaluated through labor conditions, ethical sourcing policies, community engagement, diversity initiatives, and supplier governance practices.

To enhance methodological transparency, the scoring thresholds were defined ex ante. A company received a score of 3 when most indicators within a dimension showed strong evidence of implementation and external verification; a score of 2 when evidence was mixed or only partially implemented; and a score of 1 when evidence indicated limited implementation or substantial discrepancies between reported commitments and observed practices.

The final Sustainability Score (SS) was calculated as the arithmetic mean of the three dimension scores:

$$SS = \frac{EP + TI + SR}{3}$$

This procedure allows qualitative observations to be transformed into a comparable metric while preserving the contextual richness of the case-study approach. Although the model does not claim statistical precision, it provides a transparent and replicable framework for identifying patterns across firms and for operationalizing the implementation gap discussed in the subsequent section.

3.6. Implementation Gap Conceptualization

A key contribution of the study is the introduction of the implementation gap, defined as the difference between declared sustainability commitments and observed practices. This construct provides a novel lens for analyzing discrepancies between communication and reality and offers a quantitative approximation of greenwashing intensity.

3.7. Validity and Reliability Considerations

Construct validity is ensured through the use of established theoretical frameworks, while internal validity is strengthened through cross-case comparison and pattern matching. Reliability is enhanced through transparent documentation of data sources and analytical procedures. Nonetheless, the study acknowledges the limitations associated with secondary data and the challenges of generalization.

4. Results

In order to give an empirical foundation to the previous theoretical discussion, a comparative study of seven chosen e-commerce firms was undertaken: Shopify, Patagonia, Allbirds, Vinted, H&M, Zalando, and Amazon.

The comparative study was conducted under Low–Medium–High, of established benchmarks such as Global Reporting Initiative [26] and Sustainability Accounting Standards Board [27]. The companies were evaluated based on publicly available sustainability reports when available, external audits, and third-party research/studies or databases.

Indicators were chosen to mirror the three central sustainability dimensions—environmental, social, and governance (ESG)—and facilitate comparison of the seven case-study firms. Environmental indicators are GHG emissions (Scope 1 and 2 and Scope 3 where available), use of renewable energy, use of sustainable or recycled packaging materials, and circular economy initiatives [28,29]. Social indicators are labour practice,

diversity and inclusion targets or metrics, and supply chain audits and certifications [26,30]. Governance and transparency indicators are third-party audited sustainability report disclosure, adherence to schemes like the UN Sustainable Development Goals (SDGs), ESG rating agency disclosure grades (e.g., MSCI, Sustainalytics), and greenwashing or green false claims avoidance [19,20].

The gathered data were then formatted into a comparative dataset, arrayed along the three ESG dimensions. Each firm was rated (High–Medium–Low) using a checklist based on conventional sustainability norms, but these were complemented with quantitative information where possible.

Table 1 offers an overview of the comparative study on the sustainability practice among the seven selected online businesses. All the businesses had been ranked on the basis of the following four key parameters—reporting disclosure, environmental initiatives, social responsibility, and governance policies—and then given an overall ranking of Low, Medium, or High. Such results demonstrate the extent to which all the businesses have integrated sustainability in their functioning, strategy and disclosure during the period 2019–2024.

Table 2 shows the use of blockchain in selected companies. Most companies are positioned in the early experimental phase, characterized by pilot projects and limited integration. No firm has reached full-scale implementation. The table suggests a gradual progression from experimentation to integration, with significant barriers remaining in terms of cost, scalability, and standardization.

Table 1. Integrated Comparative Assessment of Sustainability Practices.

Company	Environmental Performance	Social Responsibility	Governance & Transparency	Overall ESG Rating
Amazon	Investments in renewable energy, but increasing absolute emissions and limited supply-chain disclosure [18,28,31,32]	Workforce and community initiatives, though persistent labor controversies remain [33]	Limited third-party verification and weak transparency performance [34]	Medium–Low
Zalando	Circularity pilots and carbon-reduction targets, although implementation remains partial [35,36]	Diversity and labor commitments with moderate coverage [37]	GRI/SASB alignment and externally audited reporting [26]	Medium
H&M	Sustainability initiatives constrained by the fast-fashion business model and overproduction concerns [20,38,39]	Worker protection programs, but recurring supply-chain criticisms [40]	Greenwashing allegations and limited verification mechanisms [41]	Medium–Low
Shopify	Climate Fund investments and carbon-removal initiatives [42,43]	Support for inclusive entrepreneurship and merchant sustainability tools [42]	Relatively transparent reporting with partial external validation [26]	Medium–High
Patagonia	Strong circular economy practices, repair programs, and responsible sourcing [22,39]	Extensive stakeholder engagement and worker-focused initiatives [44]	High transparency, external audits, and B Corp certification [22]	High

Table 1. *Cont.*

Company	Environmental Performance	Social Responsibility	Governance & Transparency	Overall ESG Rating
Allbirds	Product-level carbon footprint disclosure and science-based targets [45,46]	Strong labor and ethical sourcing commitments [37]	Verified sustainability metrics and B Corp certification [47]	High
Vinted	Circular business model promoting reuse and waste reduction [48,49]	Positive consumer sustainability impact but less formalized labor policies [50]	Moderate transparency and limited external verification [51]	Medium–High

Source: own elaboration.

Table 2. Companies and Blockchain for Sustainability. Source: Own elaboration.

Company	Blockchain for Sustainability?	Use Case & Application	Partners/Platform/Documents	Source
Amazon	**No**	No active blockchain projects for supply-chain sustainability. Relies on audits, data reporting, and Climate Pledge initiatives.	Amazon Sustainability Report 2023	[52]
Zalando	**No** *	Participated in a 2022 pilot tracing organic cotton using blockchain, but no ongoing program.	Fashion for Good, 2026	[53–55]
H&M Group	**Yes**	Blockchain traceability for sustainable fibers (cellulosic, recycled polyester).	TextileGenesis	[56,57]
Shopify	**No**	Sustainability focus on carbon removal and offsets, not blockchain.	Shopify Climate Report 2024	[58]
Patagonia	**No**	Transparency via certifications (Bluesign®, Fair Trade, RWS) and Footprint Chronicles. No blockchain in use.	Patagonia Impact Report 2022	[59]
Allbirds	**No**	Uses LCA and carbon footprint labelling, not blockchain.	Allbirds Sustainability Report 2023	[60]
Vinted	**No**	Circular economy model lowers emissions. No blockchain use.	–	[61,62]

* Zalando participated in pilot only (not a scaled, not active). Source: own elaboration.

Table 3 which presents the scores assigned to the companies analyzed along the three dimensions considered—Environmental Performance (EP), Transparency Index (TI), and Social Responsibility (SR)—as well as the composite sustainability score (SS).

Table 3. Sustainability Scoring Across Case Study Firms.

Company	Environmental Performance (EP)	Transparency Index (TI)	Social Responsibility (SR)	Sustainability Score (SS)
Patagonia	3	3	3	3.0
Allbirds	3	3	2	2.7
Shopify	2	2	2	2.0
Zalando	2	2	2	2.0
Vinted	2	1	2	1.7
Amazon	1	1	2	1.3
H&M	1	1	1	1.0

Source: own elaboration.

The analysis in Table 3 clearly shows that only a limited number of companies achieve high and consistent levels across all dimensions. In particular, Patagonia and Allbirds emerge as virtuous cases, with high scores in terms of both environmental performance and transparency, suggesting a strong integration between sustainable strategy and business operations. Their positioning indicates a substantial alignment between statements and practices, which translates into a minimal implementation gap. Conversely, large companies with more complex global supply chains, such as Amazon and H&M, show significantly lower scores, especially in the transparency dimension. In these cases, the distance between communication and implementation appears more pronounced, suggesting the presence of greenwashing dynamics. The composite sustainability score for these companies is below 1.5, highlighting a weak integration of sustainable practices within operational processes. A particularly relevant element that emerges from the analysis is the positive relationship between transparency and environmental performance. Companies with a high Transparency Index also tend to show better results in terms of Environmental Performance. This result suggests that transparency is not simply a communicative dimension, but represents an enabling factor for a more effective implementation of environmental policies. The specific indicators used for each dimention are summarized in Table 4.

Table 4. Operational Indicators for Sustainability Dimensions.

Dimension	Indicator	Description	Measurement Approach
Environmental Performance (EP)	Carbon Emissions	Total greenhouse gas emissions associated with logistics and operations	Scope 1, 2, 3 disclosures and estimated logistics emissions
Environmental Performance (EP)	Packaging Efficiency	Extent to which packaging is minimized, recyclable, or reusable	Share of sustainable materials and packaging optimization initiatives
Environmental Performance (EP)	Reverse Logistics Impact	Environmental burden of product returns and reverse supply chains	Return rates and reuse/recycling policies
Environmental Performance (EP)	Energy Usage	Use of renewable energy and energy efficiency practices	Percentage of renewable energy and energy intensity metrics
Transparency Index (TI)	ESG Disclosure Quality	Depth, clarity, and completeness of sustainability reporting	Presence of standardized ESG reports and external verification

Table 4. *Cont.*

Dimension	Indicator	Description	Measurement Approach
Transparency Index (TI)	Supply Chain Traceability	Ability to track products and processes across supply chains	Disclosure of supplier tiers and traceability systems
Transparency Index (TI)	Third-Party Verification	Use of independent audits or certifications	Presence of verified certifications (e.g., B Corp, ISO)
Transparency Index (TI)	Data Accessibility	Availability of sustainability data to stakeholders	Public access to reports and datasets
Social Responsibility (SR)	Labor Conditions	Working conditions across supply chains	Policies, audits, and reported violations
Social Responsibility (SR)	Ethical Sourcing	Use of responsible sourcing practices	Supplier codes of conduct and compliance programs
Social Responsibility (SR)	Consumer Impact	Initiatives affecting consumer awareness and behavior	Sustainability labels, education campaigns
Social Responsibility (SR)	Community Engagement	Contributions to local communities and social initiatives	Investments, partnerships, and reported outcomes

Source: own elaboration.

Table 5 illustrates the operational indicators used for the construction of the three analytical dimensions.

Table 5. Implementation Gap Across Case Study Firms.

Company	Declared Commitment (DC)	Observed Performance (SS)	Implementation Gap (IG = DC − SS)
Patagonia	3.0	3.0	0.0
Allbirds	3.0	2.7	0.3
Shopify	2.5	2.0	0.5
Zalando	2.5	2.0	0.5
Vinted	2.3	1.7	0.6
Amazon	2.5	1.3	1.2
H&M	2.5	1.0	1.5

Source: own elaboration.

The articulation of the indicators highlights how environmental performance is assessed through concrete and observable variables, while transparency is measured not only in terms of reporting, but also in terms of traceability and independent verifiability. This methodological approach makes it possible to overcome a purely declarative view of sustainability, anchoring it to comparable and replicable metrics. The joint analysis of the two tables also makes it possible to identify the so-called implementation gap more precisely. This gap emerges with particular evidence in cases where high levels of disclosure are not accompanied by corresponding operational results. However, it is interesting to note that the opposite phenomenon is less frequent, suggesting that transparency is a fundamental prerequisite for the credibility of sustainable strategies. A further significant result concerns the still marginal role of blockchain technology. Despite its theoretical potential to improve traceability and reduce information asymmetries [63], none of the companies analyzed has reached an advanced level of implementation. The initiatives observed are

mainly in an experimental phase, limited to specific segments of the supply chain. Overall, the results confirm that sustainability in the e-commerce sector is not determined by the size of the company, but by the degree of strategic integration and the quality of transparency. The presence of a significant implementation gap in several cases highlights the need to develop more effective tools for verifying practices [64].

Table 5 introduces a quantitative formalization of the implementation gap [65], defined as the difference between the level of declared commitment (DC) and the performance actually observed (Sustainability Score, SS) [66].

This construct is intended to capture the degree of alignment between corporate sustainability communication and actual implementation outcomes, thereby providing a proxy for potential greenwashing dynamics.

To ensure methodological independence, the two components of the indicator—Declared Commitment (DC) and Sustainability Score (SS)—were derived through separate coding procedures.

The Sustainability Score (SS) reflects observed performance and is calculated from the semi-quantitative assessment described in Section 3.5. It is based on evidence relating to environmental performance, transparency, and social responsibility obtained through data triangulation from corporate reports, ESG databases, NGO assessments, certification schemes, and independent sources.

In contrast, the Declared Commitment (DC) score measures the intensity of sustainability commitments communicated by each company and is based exclusively on corporate disclosures rather than implementation outcomes. The coding process focused on publicly stated sustainability ambitions, strategic targets, climate pledges, ESG objectives, circular economy commitments, and net-zero declarations reported in sustainability reports, annual reports, and official corporate communications.

A three-point scale was adopted:

- DC = 1 (Low Commitment): sustainability commitments are limited, generic, or largely compliance-oriented, with few measurable long-term targets.
- DC = 2 (Moderate Commitment): the company communicates multiple sustainability objectives and medium-term targets, but commitments remain partially defined or limited in scope.
- DC = 3 (High Commitment): the company publicly communicates ambitious and comprehensive sustainability strategies, including measurable long-term targets, science-based commitments, net-zero objectives, supply-chain sustainability goals, and extensive ESG disclosures.

To improve reliability, commitment scores were assigned based on the consistency and ambition of publicly declared objectives rather than on evidence of their achievement. Consequently, a company could receive a high DC score despite obtaining a lower Sustainability Score if implementation outcomes did not match its stated ambitions.

The Implementation Gap was therefore calculated as:

$$IG = DC - SS$$

where larger positive values indicate a greater discrepancy between communicated commitments and observed sustainability performance.

This indicator allows the concept of greenwashing to be systematically operationalized, transforming it from a qualitative construct to a comparable metric between companies. The results highlight a highly asymmetrical distribution of the gap between the companies analyzed. Patagonia represents a virtuous borderline case, with zero value of the implementation gap, indicating perfect consistency between statements and practices. This

suggests a high integration of sustainability into the corporate strategy and a level of transparency such as to make the information fully verifiable. Allbirds shows a small gap (0.3), which can be interpreted as physiological in the presence of ambitious strategies but realistically subject to operational constraints. In this case, the discrepancy between statements and results does not appear to be attributable to greenwashing practices, but to a margin for improvement in implementation. In contrast, intermediate companies such as Shopify and Zalando have a moderate gap (0.5), which signals a partial disconnect between communication and performance. This level of gap suggests the presence of sustainability strategies that are still in the consolidation phase, in which the stated objectives are not fully supported by consistent operating results. The case of Vinted shows a slightly higher gap (0.6), indicating a greater criticality in the ability to translate declared commitments into concrete results. This figure is particularly relevant considering the positioning of the company as a circular economy platform, which should theoretically imply a high consistency between mission and performance.

The highest values of the implementation gap are observed for Amazon (1.2) and H&M (1.5), which represent the most critical cases in the sample. In these situations, the distance between statements and practices is significant and suggests the presence of dynamics attributable to greenwashing. In particular, the high gap can be interpreted as the result of advanced communication strategies not accompanied by an adequate level of operational transformation, often due to the complexity of global supply chains and the difficulty of implementing uniform standards along all production levels. Overall, Table 3 confirms that the implementation gap represents a synthetic but extremely effective indicator for assessing the credibility of sustainability strategies. Its integration with performance and transparency indicators allows for a more complete and critical view of corporate behavior, overcoming the limitations of analyses based solely on declarative data. A further important element is the inverse relationship between implementation gap and transparency index observed in previous results: more transparent companies tend to have smaller gaps, reinforcing the hypothesis that transparency acts as a disciplining mechanism, reducing the discrepancy between communication and operational reality.

The implementation gap presented in Table 5 provides a useful framework for assessing the potential role of blockchain in supporting sustainability practices in the e-commerce sector. The comparative evidence suggests that companies characterized by stronger transparency mechanisms tend to display a closer alignment between declared sustainability commitments and observed performance, whereas firms with weaker transparency practices often exhibit more substantial discrepancies between communication and implementation. These findings support the view that transparency plays a central role in enhancing the credibility of sustainability strategies.

In this context, blockchain can be interpreted as a governance and accountability mechanism capable of improving the reliability, traceability, and verifiability of sustainability information. Rather than focusing exclusively on disclosure, blockchain can contribute to creating conditions under which sustainability claims become more easily verifiable by stakeholders. This reduces information asymmetries and strengthens trust in corporate sustainability communications.

For companies characterized by a close alignment between commitments and observed practices, such as Patagonia and Allbirds, blockchain may primarily reinforce existing transparency systems by providing additional verification and traceability capabilities. In these cases, the technology can strengthen stakeholder confidence and facilitate the communication of already well-established sustainability practices.

For companies exhibiting larger implementation gaps, blockchain may offer a mechanism for improving consistency between sustainability commitments and operational

practices. Through immutable records and enhanced supply-chain traceability, organizations can improve the quality and credibility of sustainability information while reducing opportunities for selective disclosure. In this sense, blockchain can support a more transparent relationship between corporate communication and organizational performance [67].

The analysis also suggests that the effectiveness of blockchain depends on its integration across the broader supply-chain ecosystem. Since sustainability challenges frequently involve multiple actors operating across different organizational and geographical contexts, the benefits of blockchain are likely to depend on shared governance arrangements, common reporting standards, and collaborative participation among stakeholders.

Overall, the findings indicate that blockchain should be viewed not simply as a technological innovation but as an institutional mechanism that can strengthen transparency, accountability, and trust. Its principal contribution lies in supporting the alignment between sustainability commitments and operational practices, thereby helping organizations reduce implementation gaps and improve the credibility of their sustainability strategies.

5. Discussion

The conceptual model developed in this study illustrates the relationship between sustainability practices and firm performance, mediated by transparency.

The analysis reveals a complex and heterogeneous landscape of sustainability practices within the e-commerce sector. While all firms recognize the importance of sustainability, their approaches differ significantly in terms of depth, consistency, and strategic integration. Some firms demonstrate a high level of commitment, embedding sustainability into their core operations and aligning it with long-term strategic objectives. Others exhibit a more fragmented approach, characterized by extensive communication but limited operational change.

A key finding concerns the relationship between transparency and environmental performance. Firms that provide more detailed and verifiable disclosures tend to exhibit more consistent sustainability outcomes, suggesting that transparency plays a critical role in enhancing accountability. This relationship is further supported by the semi-quantitative analysis, which indicates a positive association between transparency scores and environmental performance indicators.

The concept of the implementation gap proves particularly useful in highlighting discrepancies between declared commitments and actual practices. In several cases, firms with strong sustainability narratives exhibit relatively weak operational performance, indicating the presence of greenwashing dynamics. Conversely, firms with more modest communication strategies often demonstrate higher levels of consistency between commitments and actions.

Blockchain adoption remains limited across all cases. While several companies have launched pilot projects or experimental initiatives, these applications are generally confined to specific segments of the supply chain and have not yet achieved large-scale implementation. This finding suggests that blockchain remains in an exploratory phase within the e-commerce sector, despite its recognized potential to enhance transparency, traceability, and accountability.

The limited diffusion of blockchain cannot be explained solely by technological maturity. Rather, the evidence suggests the existence of several systemic barriers that constrain large-scale adoption across global supply chains. One of the most significant challenges concerns implementation costs. The deployment of blockchain-based traceability systems often requires substantial investments in digital infrastructure, data integration, employee training, and process redesign. These costs can be particularly burdensome for suppliers op-

erating in developing countries or for small and medium-sized enterprises that frequently participate in global supply networks.

A second challenge relates to inter-organizational coordination and trust. The effectiveness of blockchain depends on the active participation of multiple actors across the supply chain, including manufacturers, logistics providers, distributors, retailers, certification bodies, and regulators. However, organizations may be reluctant to share operational information due to concerns regarding confidentiality, competitive advantage, or data ownership. As a result, achieving the level of collaboration required for a shared blockchain infrastructure remains a significant governance challenge.

Data standardization represents a further obstacle. Blockchain can only guarantee the integrity of information once data have been recorded; it cannot automatically ensure the accuracy or consistency of the original inputs. Supply chains often involve heterogeneous reporting practices, different sustainability metrics, and varying levels of digital maturity among suppliers. Without common reporting standards and harmonized sustainability indicators, blockchain risks preserving inconsistent or incomplete information rather than improving transparency.

Technological limitations also continue to affect scalability. Public blockchain systems offer high levels of decentralization and immutability but may face challenges related to transaction speed, scalability, energy consumption, and governance. Private or permissioned blockchains can address some of these operational constraints and provide greater control over access rights, but they may reduce decentralization and require stronger coordination among participating organizations. Consequently, companies face trade-offs between transparency, efficiency, governance, and scalability when selecting an appropriate blockchain architecture.

Regulatory uncertainty further complicates implementation. Sustainability reporting requirements, data protection regulations, and digital governance frameworks vary significantly across jurisdictions. The absence of universally accepted standards for blockchain-enabled sustainability reporting creates uncertainty regarding compliance, auditing procedures, and stakeholder acceptance.

These findings suggest that the future success of blockchain in sustainable e-commerce will depend not only on technological innovation but also on the development of supportive governance structures, industry-wide standards, and collaborative ecosystems. From a managerial perspective, organizations should view blockchain as part of a broader transparency strategy rather than as a stand-alone technological solution [68]. From a research perspective, future studies should investigate the organizational, institutional, and regulatory conditions that facilitate successful blockchain adoption across complex global supply chains.

Ultimately, the transition toward sustainable e-commerce requires a combination of technological innovation, strategic alignment, and institutional support.

The findings of the study have important implications for both theory and practice. From a theoretical perspective, they contribute to the literature by highlighting the central role of transparency in determining sustainability effectiveness [69]. The concept of the implementation gap provides a useful framework for understanding the dynamics of greenwashing and for assessing the credibility of corporate sustainability claims [70].

From a managerial perspective, the study underscores the importance of integrating sustainability into the core business strategy [71]. Firms that adopt a holistic approach to sustainability are more likely to achieve consistent and credible outcomes. In this context, transparency emerges as a key enabler of trust, both internally and externally.

From the practical point of view, standardization in the supply chain can help to reach the goal and to control it. Some steps are necessary: measure and disclose sustainability

indicators across the entire supply chain; analyze the risk that the transparency is not in conflict with privacy law; integrate a blockchain system with existing tools like ERP or an accounting system; and standardize packaging and returns metrics.no.

The potential role of blockchain technology is particularly noteworthy. By enhancing traceability and reducing information asymmetry, blockchain can contribute to more reliable and verifiable sustainability practices [72]. However, its adoption will require overcoming significant technical and organizational challenges, including issues related to scalability, cost, and standardization.

6. Conclusions

This study provides valuable insights into the relationship between sustainability practices, transparency, and blockchain adoption in the e-commerce sector. However, several limitations should be acknowledged when interpreting the findings.

First, the analysis relies primarily on secondary data sources, including corporate sustainability reports, ESG disclosures, NGO assessments, certification records, and publicly available documentation. Although the use of multiple sources enabled data triangulation and improved the robustness of the analysis, secondary data remain subject to important limitations. In particular, sustainability reports are often produced for external communication purposes and may therefore be influenced by social desirability effects, reputational considerations, and selective disclosure practices. Since greenwashing is itself characterized by discrepancies between communication and actual implementation, reliance on corporate disclosures may introduce an inherent risk of bias in the evaluation process.

A related limitation concerns the semi-quantitative scoring model developed in this study. While the model provides a structured and transparent framework for comparing companies, the resulting scores ultimately depend on the availability, quality, and completeness of publicly accessible information. Firms with more sophisticated reporting systems may appear more sustainable than organizations with weaker disclosure capabilities, even when underlying sustainability performance differs. Consequently, the scores should be interpreted as comparative analytical indicators rather than precise measurements of objective sustainability performance.

Another limitation derives from the case-study design and the relatively small sample of seven companies. Although the selected cases were chosen to maximize variation across business models and sustainability approaches, the findings cannot be generalized to the entire e-commerce sector. Rather, the study aims to generate theoretical and managerial insights that may inform future research in similar organizational contexts.

Future research could address these limitations through the collection of primary data capable of independently validating corporate sustainability claims. For example, supplier-level audits could provide direct evidence regarding environmental and social practices across supply chains, reducing dependence on company-reported information. Similarly, interviews with managers, employees, suppliers, certification bodies, and other stakeholders could offer valuable insights into the implementation challenges that are often not visible in public reports. Access to internal operational data, such as platform transaction records, logistics information, product traceability systems, or supply-chain performance metrics, would also enable a more rigorous assessment of the relationship between declared commitments and observed sustainability outcomes.

Future studies could further strengthen the empirical validation of the implementation gap concept by adopting mixed-methods approaches that combine qualitative case studies with survey data, longitudinal analyses, or quantitative performance indicators. Such approaches would allow researchers to examine how sustainability commitments evolve over time and whether transparency-enhancing technologies, including blockchain,

effectively contribute to reducing discrepancies between corporate communication and actual organizational practices.

Finally, future research should explore the organizational, technological, and regulatory conditions that facilitate successful blockchain adoption at scale. Particular attention should be devoted to issues such as data governance, interoperability standards, stakeholder coordination, and the integration of blockchain systems with existing sustainability reporting frameworks. Advancing knowledge in these areas would contribute to a more nuanced understanding of how transparency mechanisms can support credible and verifiable sustainability practices in increasingly complex global supply chains.

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