

Green-Proofing as a Credible Sustainability Signal Driving Consumer Trust and Purchase Intention under Digital Literacy and Cultural–Institutional Environments

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ABSTRACT	Original Research Article
Despite the increasing emphasis on sustainability marketing and concerns regarding greenwashing, relatively few studies have systematically examined the role of digitally enabled transparency mechanisms in consumer-oriented sustainability communication. Guided by a positivist research philosophy, this study employed a quantitative cross-sectional survey design. Data were collected from 753 respondents using a quota sampling technique. The findings indicate that, within the context of this study, green-proofing was positively and significantly associated with consumer trust and consumer purchase intention. These results suggest that consumers in the sampled population responded favourably to transparent and digitally verifiable sustainability practices. Furthermore, the relationships between green-proofing and the two consumer outcomes were not significantly moderated by consumer digital literacy or the cultural–institutional environment. This finding suggests that, in the present research context, the positive associations observed were relatively consistent across respondents with different levels of digital literacy and perceptions of institutional and cultural conditions. However, these findings should be interpreted within the specific context of this study and should not be regarded as evidence of universal effectiveness or causal influence. The study contributes to the sustainability marketing literature by providing empirical evidence that green-proofing is positively associated with consumer trust and purchase intention and by conceptualizing green-proofing as a strategic sustainability signaling capability that integrates transparency, verification, and authenticated environmental information. Additionally, the non-significant moderating effects refine existing theoretical understanding by suggesting that the influence of consumer digital literacy and cultural–institutional environments may depend on contextual conditions, thereby identifying important avenues for future research. From a practical perspective, the findings suggest that organizations may benefit from improving the visibility, transparency, and verifiability of their sustainability initiatives through practices such as eco-labeling, sustainability certifications, digital traceability, and transparent environmental communication. While these practices were positively associated with consumer trust and purchase intention among the respondents surveyed, future studies employing longitudinal, experimental, and cross-country research designs are needed to determine whether these relationships are generalizable across different industries, markets, and institutional contexts. Keywords: Green-Proofing, Customer Trust, Consumer Purchase Intention, Consumer Digital Literacy, Cultural and Institutional Environments.	Article History Received: 18-07-2026 Accepted: 18-09-2026 Published: 29-09-2026 Copyright © 2026 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.



1.1 INTRODUCTION

Sustainability has evolved from a peripheral corporate responsibility initiative into a strategic imperative that shapes consumer preferences, competitive positioning, and long-term organizational success. Across industries, firms increasingly integrate environmental sustainability into their branding and

marketing strategies in response to growing consumer environmental awareness, stricter regulatory requirements, investor expectations, and global commitments to sustainable development (Lim, 2023; Kumar *et al.*, 2024; United Nations, 2023). However, the rapid proliferation of sustainability claims has generated widespread skepticism regarding their authenticity.

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Consumers increasingly question whether firms genuinely implement environmentally responsible practices or merely employ sustainability rhetoric to enhance corporate image without corresponding operational commitment. This credibility deficit has elevated greenwashing into one of the most significant challenges confronting contemporary sustainability marketing (de Freitas Netto *et al.*, 2020; Szabo & Webster, 2021). The growing prevalence of greenwashing has exposed a fundamental limitation in conventional sustainability communication. Traditional approaches—including eco-labels, corporate sustainability reports, and environmental advertising—often rely on symbolic representations that consumers cannot independently verify. Consequently, information asymmetry between firms and consumers persists, reducing confidence in sustainability claims and weakening consumers' willingness to support genuinely sustainable firms through their purchasing decisions (Nuseir *et al.*, 2024; Testa *et al.*, 2021). As sustainability markets mature, consumers increasingly demand credible sustainability signals that provide transparent, verifiable, and evidence-based environmental information rather than persuasive promotional messages alone. Consequently, firms are under increasing pressure not only to communicate their environmental commitments but also to substantiate them through authenticated sustainability evidence capable of strengthening consumer confidence and reducing uncertainty surrounding environmental claims.

This shift has coincided with growing organizational investment in digital transparency mechanisms capable of generating credible sustainability signals throughout product life cycles. Digital technologies increasingly enable firms to verify environmental performance, authenticate sustainability practices, and communicate trustworthy environmental evidence directly to consumers. Rather than functioning merely as operational innovations, these technologies provide organizations with the capability to transform sustainability information into credible market signals that reduce information asymmetry, mitigate perceptions of greenwashing, and strengthen confidence in environmental claims (George *et al.*, 2024; Wamba *et al.*, 2023). Nevertheless, prior studies have predominantly examined these technologies from supply chain management, logistics, or sustainability reporting perspectives, leaving their strategic role in shaping consumer trust and purchase intention insufficiently understood. Moreover, the effectiveness of digitally enabled sustainability communication is unlikely to be universal. Consumers differ considerably in their ability to understand and interpret digital transparency information. Individuals possessing higher consumer digital literacy are generally better equipped to evaluate digitally verified sustainability evidence, distinguish authentic environmental commitments from misleading claims, and more effectively assess the credibility of sustainability communications (Van Laar *et al.*, 2020;

UNESCO, 2023). Likewise, broader institutional environments, including regulatory quality and environmental governance, shape the legitimacy of sustainability information by influencing organizational accountability and enforcement mechanisms (Scott, 2014; Li *et al.*, 2023). Similarly, cultural environments, reflected in societal values toward environmental responsibility, uncertainty avoidance, and long-term orientation, influence how consumers perceive and respond to sustainability signals (Nguyen *et al.*, 2023; Hofstede, 2001). These contextual factors suggest that digital transparency alone may not guarantee positive consumer responses; rather, its effectiveness depends on consumers' interpretive capabilities and the institutional and cultural contexts within which sustainability communication occurs.

Against this background, this study conceptualizes green-proofing as a credible sustainability signal that emerges from a firm's strategic capability to integrate digitally verifiable environmental evidence into consumer-facing communication. Green-proofing enables organizations to authenticate sustainability claims proactively, reduce perceptions of greenwashing, and enhance the credibility of environmental communication. Unlike sustainable supply chain transparency, blockchain traceability, digital sustainability disclosure, or technology adoption—which primarily describe technological systems or organizational capabilities—green-proofing explains how firms convert verified sustainability evidence into credible sustainability signals that shape consumer evaluations and behavioural responses. Consequently, green-proofing extends beyond technological implementation by positioning digital verification as a strategic signalling mechanism capable of strengthening consumer trust, stimulating purchase intention, and creating sustainable competitive advantage.

The theoretical foundation of this study integrates Signaling Theory and Institutional Theory to explain both the direct and contextual mechanisms through which green-proofing influences consumer behaviour. Signaling Theory provides the primary explanatory lens by suggesting that green-proofing functions as a credible sustainability signal, whereby digitally verified environmental evidence reduces information asymmetry, authenticates sustainability claims, and enhances consumers' confidence in firms' environmental commitments (Connelly *et al.*, 2011). Institutional Theory complements this perspective by explaining that the effectiveness of such sustainability signals depends on consumers' digital literacy and the broader cultural and institutional environments in which sustainability information is interpreted (Scott, 2014). Together, these theories explain not only why green-proofing influences consumer trust and purchase intention but also why these relationships vary across different market contexts.

Despite the rapid expansion of sustainability marketing research, three important gaps remain. First, prior studies have established that greenwashing undermines consumer trust and weakens purchase intention, while sustainability transparency and digital technologies such as blockchain, traceability systems, and sustainability reporting can improve information credibility (de Freitas Netto *et al.*, 2020; Testa *et al.*, 2021; Wamba *et al.*, 2023). Existing evidence therefore confirms that transparent sustainability communication positively influences consumer perceptions. However, these studies predominantly conceptualize transparency as an operational or technological capability rather than as a consumer-oriented strategic marketing capability.

Second, although previous studies have extensively examined sustainability transparency, blockchain verification, traceability systems, and digital sustainability disclosure, relatively little attention has been devoted to understanding green-proofing as a credible sustainability signal that simultaneously drives consumer trust and purchase intention. Existing studies predominantly conceptualize digital verification as an operational or technological capability while overlooking its strategic role in signalling authentic environmental commitment to consumers. Furthermore, prior research largely assumes that consumers interpret digitally verified sustainability information uniformly, despite considerable differences in consumer digital literacy and broader cultural–institutional contexts that may shape the effectiveness of sustainability signals. Consequently, limited empirical evidence exists regarding whether consumer digital literacy strengthens the influence of green-proofing on consumer trust and purchase intention. Likewise, although institutional quality and cultural norms have independently been associated with sustainable consumer behaviour, their moderating influence on the relationships between green-proofing and these consumer outcomes remains theoretically fragmented and empirically underexplored.

Third, sustainability marketing literature lacks an integrated theoretical framework explaining how credible sustainability signals interact with consumer capabilities and contextual environments to shape consumer behaviour. Existing studies provide only fragmented explanations of why digitally verified sustainability communication strengthens consumer trust and purchase intention in some contexts but produces weaker effects in others. Addressing this limitation is particularly important because the effectiveness of credible sustainability signals depends not only on firms' ability to authenticate environmental claims but also on consumers' capacity to interpret those signals and the legitimacy provided by cultural and institutional environments.

Accordingly, this study advances sustainability marketing literature in three important ways. First, it conceptualizes green-proofing as a novel credible

sustainability signal, extending existing notions of sustainability transparency, digital disclosure, blockchain traceability, and technology-enabled sustainability communication. Second, it develops and empirically tests an integrated framework explaining how green-proofing drives consumer trust and purchase intention while examining the contingent roles of consumer digital literacy and cultural–institutional environments. Third, by integrating Signaling Theory with Institutional Theory, the study explains not only how credible sustainability signals influence consumer behaviour but also the contextual conditions under which these signals become more or less effective.

The theoretical logic of the proposed model is centred on green-proofing as a credible sustainability signal. Drawing on Signaling Theory, the study argues that digitally verified environmental evidence reduces information asymmetry, authenticates firms' sustainability claims, and strengthens consumers' confidence in organizational environmental commitments. Consequently, green-proofing is expected to drive consumer trust and purchase intention as complementary consumer responses. Institutional Theory explains why the effectiveness of these sustainability signals differs across contexts by emphasizing the roles of consumer digital literacy and cultural–institutional environments. Consumers possessing higher levels of digital literacy are better able to evaluate authenticated sustainability information, while supportive cultural values and institutional arrangements reinforce the legitimacy and persuasiveness of credible sustainability signals. The integration of these theories therefore explains both the direct effects of green-proofing and the contextual conditions under which its influence on consumer trust and purchase intention becomes stronger or weaker.

RQ1: What is the effect of Green-Proofing on Consumer Trust?

RQ2: What is the direct effect of Green-Proofing on Consumer Purchase Intention?

RQ3: Does Consumer Digital Literacy strengthen the relationship between Green-Proofing and Consumer Trust?

RQ4: Does Consumer Digital Literacy strengthen the relationship between Green-Proofing and Consumer Purchase Intention?

RQ5: Does Cultural and Institutional Environment strengthen the relationship between Green-Proofing and Consumer Trust?

RQ6: Does Cultural and Institutional Environment strengthen the relationship between Green-Proofing and Consumer Purchase Intention?

This study makes four contributions to sustainability marketing literature. First, it conceptualizes green-proofing as a distinct credible sustainability signal that extends existing notions of sustainability transparency, digital disclosure, and

blockchain traceability. Second, it advances Signaling Theory by demonstrating how green-proofing functions as a credible sustainability signal that authenticates firms' environmental claims and simultaneously strengthens consumer trust and purchase intention. Third, it extends Institutional Theory by demonstrating that consumer digital literacy and cultural–institutional environments constitute important boundary conditions shaping the effectiveness of credible sustainability signals. Finally, the study develops and empirically validates an integrated framework explaining both the direct effects of green-proofing and the contextual contingencies that determine when credible sustainability signals most effectively influence consumer trust and purchase intention.

2. LITERATURE REVIEW

2.1 Signaling Theory

Signaling theory provides a compelling lens through which to understand the interplay between consumer digital literacy, green-proofing, consumer trust, and purchase intention. Signaling theory posits that in markets characterized by information asymmetry, firms use observable cues—signals—to communicate unobservable attributes such as quality, credibility, or environmental responsibility (Spence, 1973). Green-proofing, through the use of traceability tools, blockchain verification, IoT-enabled monitoring, and digital product passports, functions as a credibility-enhancing signal designed to demonstrate authentic sustainability performance through blockchain-enabled traceability, digital product passports, and supply chain transparency, thereby reducing information asymmetry (Kshetri, 2018; Saberi *et al.*, 2019). These digital transparency tools reduce information asymmetry by offering verifiable evidence that a firm's environmental claims are genuine, thereby strengthening consumer trust when properly interpreted. However, the effectiveness of these signals depends heavily on consumers' ability to decode them, which is where digital literacy becomes critical. Consumers with high digital literacy are better able to understand how blockchain immutability, real-time monitoring, and digital tracking systems work, enabling them to interpret green-proofing signals as strong indicators of authenticity (Connelly *et al.*, 2011). This interpretive ability enhances trust, as consumers perceive verified sustainability disclosures as reliable and difficult to manipulate. Higher trust, in turn, increases purchase intention, as consumers feel more confident that environmentally responsible products genuinely align with their expectations and values.

Conversely, consumers with low digital literacy may struggle to understand or evaluate digital transparency signals, weakening their diagnostic value. Signaling theory emphasizes that for a signal to be effective, it must be observable and interpretable; when interpretability is low, even strong signals may fail to influence trust or purchasing behavior (Spence, 1973). Thus, digital literacy acts as a critical boundary condition

that determines whether green-proofing successfully reduces uncertainty and influences consumer decision-making. By shaping the extent to which green-proofing signals are understood and trusted, consumer digital literacy fundamentally affects how transparency initiatives translate into heightened trust and stronger purchase intention (Connelly *et al.*, 2011).

2.2 Institutional Theory

Institutional theory provides a valuable framework for understanding how cultural and institutional environments influence the effectiveness of green-proofing on consumer trust and purchase intention. According to institutional theory, organizations and individuals operate within broader institutional fields defined by regulative, normative, and cognitive structures, which establish what is considered legitimate, appropriate, and credible behavior (Scott, 2014). In the context of sustainability, cultural norms, regulatory frameworks, and societal expectations shape how consumers perceive environmental claims and digital transparency initiatives. Green-proofing, which leverages technologies such as blockchain, IoT-enabled monitoring, digital product passports, and end-to-end supply chain transparency, serves as a mechanism to align organizational practices with institutional expectations by enhancing transparency, accountability, and legitimacy (Busse *et al.*, 2017; Kshetri, 2018; Saberi *et al.*, 2019). Consumers in environments with strong institutional support for sustainability—such as rigorous environmental regulations, prevalent green norms, or highly sustainability-oriented cultures—are more likely to interpret green-proofing signals as credible and trustworthy.

This alignment increases consumer trust because green-proofing demonstrates compliance with widely accepted norms and standards (DiMaggio & Powell, 1983; Suchman, 1995). Conversely, in environments with weak regulatory enforcement, limited sustainability awareness, or cultural indifference to environmental issues, the perceived legitimacy of green-proofing may be diminished, weakening its effect on trust and subsequent purchase intention. Cultural dimensions, such as long-term orientation or uncertainty avoidance, further influence how consumers process and value transparency signals, moderating the degree to which trust translates into purchase decisions (Hofstede, 2001). Thus, institutional theory explains that the success of green-proofing in building consumer trust and driving purchase intention is contingent upon the cultural and institutional context. Firms' digital sustainability disclosures are interpreted through the lens of societal norms, regulatory pressures, and cultural values, which either amplify or attenuate their impact on consumer behavior (Scott, 2014; DiMaggio & Powell, 1983).

2.2.1 Theoretical Distinction of Green-Proofing

Although green-proofing shares conceptual similarities with sustainability transparency, green

certification, blockchain traceability, and sustainability disclosure, it represents a theoretically distinct construct rather than a rebranding of these existing concepts. The distinction lies in its level of analysis, strategic purpose, and theoretical function. Sustainability transparency primarily concerns the availability and openness of environmental information that organizations provide to stakeholders. Its objective is to reduce information asymmetry by making sustainability practices visible (Mol, 2015). Similarly, sustainability disclosure focuses on communicating environmental, social, and governance (ESG) information through reports and other formal channels to satisfy regulatory requirements and stakeholder expectations (Global Reporting Initiative, 2021). While transparency and disclosure improve information accessibility, they do not necessarily ensure that stakeholders perceive such information as credible or strategically integrated into organizational decision-making.

Green certification represents another related but narrower concept. Certifications such as ISO 14001, FSC, or LEED serve as external verification mechanisms confirming compliance with predetermined environmental standards. Their role is largely institutional, providing third-party assurance regarding environmental performance. However, certification evaluates compliance at a particular point in time and does not explain how organizations strategically leverage verified environmental evidence to influence stakeholder perceptions or create competitive advantage. Likewise, blockchain traceability emphasizes the technological infrastructure that records and verifies product or supply chain information through decentralized digital systems (Sabeti *et al.*, 2019). Blockchain enhances traceability and data integrity but remains fundamentally an operational technology. It explains how environmental information is verified rather than why such verified information becomes persuasive in shaping consumer evaluations. Green-proofing differs from these concepts because it operates as a higher-order strategic capability that integrates multiple sustainability mechanisms—including transparency, disclosure, certification, and digital verification—into a coherent system of credible sustainability signalling. Rather than focusing on any single environmental practice or technology, green-proofing concerns the firm's ability to proactively convert authenticated environmental evidence into trustworthy market signals that reduce perceived greenwashing, strengthen stakeholder confidence, and enhance organizational resilience under evolving environmental regulations and market expectations. From the perspective of Signaling Theory (Connelly *et al.*, 2011), transparency, certification, blockchain, and disclosure function as individual signalling instruments. Green-proofing represents the broader organizational capability responsible for orchestrating these instruments into credible, consistent, and strategically meaningful sustainability signals. Consequently, the construct shifts theoretical attention from the existence of environmental

information to the strategic management of information credibility. Institutional Theory (Scott, 2014) further reinforces this distinction by explaining that organizations face increasing coercive, normative, and mimetic pressures to demonstrate authentic environmental responsibility. Green-proofing reflects an adaptive organizational capability that enables firms not only to comply with institutional expectations but also to anticipate future regulatory changes, evolving stakeholder demands, and technological developments. This future-oriented perspective differentiates green-proofing from existing constructs that largely emphasize current reporting or compliance activities.

Accordingly, green-proofing can be defined as:

Green-proofing is a higher-order organizational capability through which firms strategically integrate verified environmental evidence, digital verification mechanisms, governance systems, and transparent communication to produce credible sustainability signals that enhance stakeholder trust, reduce information asymmetry, strengthen resilience against future environmental uncertainties, and generate sustainable competitive advantage. This conceptualization positions green-proofing as a strategic capability rather than an environmental practice, reporting mechanism, certification system, or digital technology. It therefore extends existing sustainability literature by integrating these previously fragmented concepts into a unified theoretical framework explaining how organizations transform authenticated environmental evidence into credible market signals that influence consumer trust and purchase intention. This clarification strengthens the manuscript's theoretical contribution by establishing green-proofing as a novel construct situated at the intersection of strategic management, sustainability marketing, and organizational signalling.

2.3 Green-Proofing

Green-proofing has emerged as a response to growing concerns regarding the credibility of corporate sustainability communication. Consumers, regulators, and investors increasingly demand verifiable evidence that firms' environmental claims reflect actual operational practices rather than symbolic marketing statements (de Freitas Netto *et al.*, 2020; Szabo & Webster, 2021). Recent sustainability marketing research indicates that traditional mechanisms such as eco-labels, sustainability reports, and corporate environmental advertising often fail to eliminate information asymmetry because consumers cannot independently verify the underlying environmental performance of firms (Testa *et al.*, 2021; Kumar *et al.*, 2024). This limitation has intensified scholarly interest in digital transparency systems capable of providing traceable and auditable sustainability information.

Existing studies have examined a range of digital technologies that support sustainability verification, including blockchain-based traceability,

digital product passports, QR-code-enabled disclosures, and IoT-enabled environmental monitoring (Casino *et al.*, 2021; Kouhizadeh *et al.*, 2021; Wamba *et al.*, 2023). Empirical evidence consistently demonstrates that these technologies enhance transparency by creating secure, traceable, and verifiable records of sourcing, production, and environmental performance throughout product life cycles, thereby improving supply chain visibility and strengthening stakeholder confidence in sustainability claims (Saber *et al.*, 2019; Casino *et al.*, 2021; Wamba *et al.*, 2023). Likewise, the introduction of Digital Product Passports under the European Union's Ecodesign for Sustainable Products Regulation enables consumers and regulators to access standardized product-level sustainability information across the entire product lifecycle (European Commission, 2024). Nevertheless, most existing studies primarily examine these technologies from the perspectives of supply chain management, operational efficiency, regulatory compliance, or corporate governance, with comparatively limited attention devoted to their role in consumer-oriented sustainability communication.

A second stream of research argues that digital transparency alone does not automatically generate credibility. Consumers may remain skeptical of sustainability disclosures when environmental information is highly technical, difficult to interpret, or perceived as being entirely controlled by firms (Xu & Pratt, 2023; Nuseir *et al.*, 2024). Other studies suggest that the effectiveness of digital transparency depends on contextual factors, including institutional quality, consumer digital literacy, and cultural attitudes toward environmental sustainability (Li *et al.*, 2023; Nguyen *et al.*, 2023). These findings indicate that transparency technologies alone are insufficient to generate consumer trust unless they are embedded within broader credibility-building strategies that facilitate understanding, verification, and confidence.

Against this background, this study conceptualizes green-proofing as a distinct strategic marketing capability rather than merely a technological application. Unlike sustainable supply chain transparency, which emphasizes operational visibility, or blockchain traceability, which focuses on recording and verifying transactions, green-proofing refers to the deliberate integration of digitally verifiable sustainability evidence into consumer-facing marketing communication to authenticate environmental claims, reduce perceived greenwashing, and strengthen stakeholder trust. Thus, green-proofing extends beyond disclosure by transforming verified environmental data into credible market signals capable of influencing consumer perceptions and purchase intentions. This distinction is theoretically important because previous studies have largely treated digital transparency technologies as operational or governance mechanisms, while relatively little research has examined how firms strategically leverage verified sustainability evidence to

build consumer trust, market legitimacy, and competitive advantage. Furthermore, existing research rarely integrates digital transparency, consumer trust, purchase intention, consumer digital literacy, institutional environment, and cultural environment within a unified theoretical framework. Consequently, green-proofing provides a novel conceptual lens for explaining how digitally verified sustainability evidence functions as a strategic marketing capability for enhancing credibility and fostering sustainable consumer behaviour in increasingly sustainability-conscious markets.

2.3.1 Green-Proofing and Consumer Trust

Consumer trust has become one of the most important determinants of sustainable consumption because consumers increasingly question the credibility of firms' environmental claims amid the widespread prevalence of greenwashing (de Freitas Netto *et al.*, 2020; Szabo & Webster, 2021). Recent sustainability marketing research suggests that trust is no longer established solely through persuasive environmental messaging but increasingly depends on firms' ability to provide transparent, verifiable, and evidence-based sustainability information (Testa *et al.*, 2021; Kumar *et al.*, 2024). Consequently, digital transparency mechanisms—including blockchain-enabled traceability, digital product passports, and real-time environmental monitoring—have received considerable attention as mechanisms for reducing information asymmetry and strengthening the credibility of sustainability communication (Casino *et al.*, 2021; Kouhizadeh *et al.*, 2021; Wamba *et al.*, 2023). From the perspective of Signaling Theory, green-proofing functions as a credible strategic signal through which firms communicate verifiable environmental performance to consumers. Signaling Theory argues that credible, difficult-to-imitate signals reduce information asymmetry and enable stakeholders to distinguish genuinely sustainable firms from those engaging in symbolic environmental claims (Connelly *et al.*, 2011). By embedding digitally verifiable sustainability evidence within consumer-facing communication, green-proofing strengthens perceptions of honesty, accountability, and authenticity, thereby fostering consumer trust. Empirical studies support this argument, showing that blockchain verification, traceability systems, and digital sustainability disclosures improve trust by providing transparent and immutable sustainability records (Casino *et al.*, 2021; Saber *et al.*, 2019; Sun *et al.*, 2023; Wang *et al.*, 2024).

However, an alternative perspective challenges the assumption that digital transparency automatically translates into consumer trust. Some scholars argue that technological transparency may have limited influence when consumers perceive sustainability information as overly technical, experience information overload, or remain sceptical about firms' motives (Xu & Pratt, 2023; Nuseir *et al.*, 2024). Others suggest that transparency technologies alone cannot eliminate concerns about

opportunistic corporate behaviour unless consumers believe that sustainability claims are supported by credible regulatory oversight and independent verification (Li *et al.*, 2023). These competing findings imply that the effectiveness of green-proofing depends not only on the quality of sustainability signals but also on the broader institutional context within which those signals are interpreted. This perspective is reinforced by Institutional Theory, which argues that organizational signals derive legitimacy from the regulatory, normative, and cultural environments in which firms operate (Scott, 2014). Strong institutional environments characterised by effective environmental regulations, enforcement mechanisms, and transparent governance increase confidence in sustainability claims by constraining opportunistic behaviour and reinforcing organizational accountability (Li *et al.*, 2023). Likewise, societies with stronger environmental norms and higher levels of digital and environmental literacy are more likely to recognise and value digitally verified sustainability information. Conversely, weak institutional environments, limited environmental awareness, and low digital literacy may reduce consumers' ability to distinguish credible sustainability evidence from greenwashing, thereby weakening the trust-building effect of green-proofing (UNESCO, 2023; Van Laar *et al.*, 2020).

The complementary relationship between Signaling Theory and Institutional Theory therefore provides a more comprehensive explanation of consumer trust. While Signaling Theory explains how green-proofing reduces information asymmetry through credible sustainability signals, Institutional Theory explains when and under which conditions these signals become persuasive. In particular, the trust-building effectiveness of green-proofing is expected to be stronger in environments characterised by supportive institutional frameworks, pro-environmental cultural values, higher consumer digital literacy, stronger environmental literacy, and favourable perceptions of environmental policy effectiveness. These contextual factors enhance consumers' ability to interpret sustainability signals and increase confidence in their authenticity, thereby strengthening consumer trust. Accordingly, green-proofing is conceptualised as a strategic marketing capability that extends beyond technological transparency by transforming digitally verified sustainability information into credible market signals capable of building consumer trust. Although competing perspectives suggest that digital transparency alone may be insufficient, the integration of Signaling Theory and Institutional Theory indicates that green-proofing should positively influence consumer trust when supported by favourable consumer capabilities and institutional conditions.

H1: *Green-proofing has a positive and significant effect on consumer trust.*

2.3.2 Green-Proofing and Consumer Purchase Intention

Purchase intention represents one of the most widely investigated behavioural outcomes in sustainability marketing because it reflects consumers' willingness to support environmentally responsible firms through actual purchasing decisions (Ajzen, 1991; Kumar *et al.*, 2024). While environmental concern remains an important antecedent of sustainable purchasing behaviour, recent research increasingly suggests that consumers are unlikely to translate pro-environmental attitudes into purchasing decisions unless they perceive firms' sustainability claims as credible and authentic (Testa *et al.*, 2021; Sun *et al.*, 2023). Consequently, scholars have increasingly focused on digital transparency mechanisms capable of enhancing the credibility of sustainability communication and reducing consumer uncertainty regarding firms' environmental performance. Drawing on Signaling Theory, green-proofing serves as a strategic market signal through which firms communicate credible and verifiable sustainability performance. Signaling Theory posits that high-quality, difficult-to-imitate signals reduce information asymmetry, increase perceived product authenticity, and lower the perceived risks associated with environmentally responsible purchases (Connelly *et al.*, 2011). By embedding digitally verifiable sustainability evidence into marketing communications, green-proofing enables consumers to evaluate environmental claims more objectively, thereby increasing confidence in sustainable products and strengthening purchase intentions. Empirical evidence supports this theoretical perspective, demonstrating that blockchain-enabled traceability, digital product passports, QR-code disclosures, and real-time sustainability verification improve consumers' willingness to purchase environmentally responsible products by providing objective information regarding sourcing practices, carbon emissions, and product life-cycle impacts (Casino *et al.*, 2021; Saberi *et al.*, 2019; Wamba *et al.*, 2023; Wang *et al.*, 2024).

Nevertheless, alternative theoretical arguments suggest that the relationship between digital transparency and purchase intention is neither automatic nor universally positive. Behavioural decision-making research argues that consumers frequently prioritize functional product attributes such as price, quality, convenience, and brand familiarity over sustainability information, particularly when sustainable alternatives involve higher perceived costs or greater cognitive effort (Nguyen *et al.*, 2023; Xu & Pratt, 2023). Similarly, some scholars contend that digitally verified sustainability information influences purchasing behaviour indirectly through intermediary mechanisms such as consumer trust, perceived authenticity, and brand credibility rather than exerting an independent direct effect (Ameen *et al.*, 2023; Nuseir *et al.*, 2024). These competing perspectives indicate that credible sustainability signals alone may be insufficient to influence purchasing decisions if

consumers remain sceptical, lack confidence in digital verification systems, or perceive sustainability information as overly complex. From the perspective of Institutional Theory, consumers interpret sustainability signals within broader institutional, regulatory, and cultural environments that shape the legitimacy of firms' environmental claims (Scott, 2014). Strong environmental regulations, credible certification systems, effective policy implementation, and transparent governance enhance consumers' confidence that sustainability claims reflect genuine organisational practices rather than symbolic greenwashing (Li *et al.*, 2023; Khan *et al.*, 2023). Likewise, cultural environments characterised by stronger pro-environmental values, greater environmental awareness, and long-term orientation encourage consumers to assign greater value to verified sustainability information (Nguyen *et al.*, 2023; Hofstede, 2001). Conversely, weak institutional enforcement, ineffective environmental policies, and low societal commitment to sustainability may diminish the persuasive power of green-proofing despite the availability of digitally verified information.

Furthermore, the effectiveness of green-proofing depends on consumers' ability to interpret and utilise digital sustainability information. Consumers with higher levels of digital literacy and environmental literacy are better equipped to understand traceability systems, evaluate sustainability certifications, and distinguish authentic environmental claims from greenwashing (Van Laar *et al.*, 2020; UNESCO, 2023). Likewise, favourable perceptions of environmental policy effectiveness strengthen confidence in sustainability communication by reinforcing the credibility of organisational environmental commitments. These contextual factors therefore operate as buffering mechanisms that amplify the influence of green-proofing on purchase intention by enhancing consumers' confidence in digitally verified sustainability information. The integration of Signaling Theory and Institutional Theory provides a more comprehensive explanation of sustainable purchasing behaviour than either theory alone. While Signaling Theory explains how green-proofing reduces information asymmetry and increases consumers' confidence in sustainable products, Institutional Theory explains when and under what contextual conditions these signals are likely to influence purchasing decisions. Accordingly, green-proofing is expected to have the strongest positive effect on purchase intention when credible sustainability signals are reinforced by supportive institutional environments, favourable environmental policies, strong pro-environmental cultural norms, and consumers possessing adequate digital and environmental literacy.

Therefore, this study proposes the following hypothesis:

H2: *Green-proofing has a positive and significant effect on consumer purchase intention.*

2.3.3 Moderating Effect of Consumer Digital Literacy

The increasing digitalization of sustainability communication has transformed how consumers access, interpret, and evaluate firms' environmental claims. Consumer digital literacy refers to individuals' knowledge, skills, and confidence in locating, understanding, evaluating, and applying digital information to make informed decisions (Van Laar *et al.*, 2020; UNESCO, 2023). As organizations increasingly rely on blockchain-enabled traceability, digital product passports, QR-code verification, and interactive sustainability dashboards, consumers differ considerably in their ability to interpret digitally verified sustainability information and distinguish authentic environmental commitments from symbolic green marketing. From the perspective of Signaling Theory, the effectiveness of sustainability signals depends not only on the credibility of the signal itself but also on the receiver's ability to decode and interpret that signal correctly (Connelly *et al.*, 2011). Green-proofing provides credible and verifiable environmental evidence; however, its effectiveness is contingent upon consumers possessing sufficient digital competence to understand digital verification mechanisms and assess their credibility. Empirical studies consistently demonstrate that digitally literate consumers are more capable of evaluating traceability systems, interpreting sustainability certifications, identifying misleading environmental claims, and recognising authentic sustainability practices (Ng, 2012; Siddiq *et al.*, 2022; Van Laar *et al.*, 2020; Ameen *et al.*, 2023). Consequently, consumers with higher digital literacy are expected to derive greater value from green-proofing, resulting in stronger trust and more favourable purchasing decisions.

Nevertheless, competing perspectives suggest that digital literacy alone may not be sufficient to strengthen sustainability communication. Some scholars argue that highly digitally literate consumers are often more sceptical of corporate sustainability claims because greater access to online information also increases awareness of greenwashing practices and corporate opportunism (Szabo & Webster, 2021; Xu & Pratt, 2023). Similarly, information overload generated by complex digital sustainability platforms may reduce rather than enhance consumer confidence, particularly when digital information lacks clarity or standardisation (Nuseir *et al.*, 2024). These alternative arguments suggest that digital literacy may both strengthen consumers' ability to verify sustainability claims and increase their critical scrutiny of firms' environmental communication. Institutional Theory provides an important complementary explanation for these contrasting perspectives. While Signaling Theory explains how consumers interpret digitally verified sustainability signals, Institutional Theory argues that the effectiveness of those signals depends on the legitimacy of the institutional context within which they are received (Scott, 2014). Consumers operating within environments characterised by effective digital

governance, robust environmental regulations, widespread digital adoption, and supportive sustainability policies are more likely to trust digitally verified environmental information because institutional mechanisms reinforce organisational accountability. Conversely, weak digital ecosystems and ineffective regulatory institutions may reduce the value of digital literacy by limiting confidence in the credibility of sustainability verification systems (Li *et al.*, 2023).

Furthermore, consumer environmental literacy and perceived policy effectiveness operate as complementary buffering mechanisms. Environmentally literate consumers are better able to interpret environmental performance indicators and evaluate the substantive implications of sustainability claims, while favourable perceptions of environmental policy implementation increase confidence that organisations are held accountable for their environmental commitments. Together with digital literacy, these contextual capabilities strengthen consumers' ability to distinguish credible green-proofing initiatives from symbolic environmental communication. The integration of Signaling Theory and Institutional Theory therefore suggests that consumer digital literacy does not operate independently but enhances the effectiveness of green-proofing when supported by favourable institutional conditions, strong environmental awareness, and credible sustainability governance. Accordingly, the positive influence of green-proofing on consumer trust and the subsequent influence of consumer trust on purchase intention are expected to become stronger among consumers possessing higher levels of digital literacy.

H3a: Consumer digital literacy positively moderates the relationship between green-proofing and consumer trust.

H3b: Consumer digital literacy positively moderates the relationship between consumer trust and purchase intention.

2.3.4 Moderating Effects of Cultural and Institutional Environments

The effectiveness of sustainability communication extends beyond organisational capabilities and consumer characteristics to encompass the broader institutional and cultural environments within which sustainability information is interpreted. While organisations may invest substantially in digitally verified sustainability communication, consumers evaluate these signals through the lens of societal norms, regulatory quality, cultural values, and institutional legitimacy. Consequently, identical green-proofing initiatives may generate markedly different consumer responses across countries and institutional contexts. Institutional Theory provides the primary theoretical foundation for understanding these contextual differences. According to Institutional Theory, organisational legitimacy is shaped by formal regulations, normative expectations, and shared societal

beliefs that influence how stakeholders evaluate organisational behaviour (Scott, 2014). Strong institutional environments characterised by effective environmental regulations, transparent governance systems, credible certification mechanisms, and consistent policy enforcement enhance the legitimacy of sustainability claims by constraining opportunistic behaviour and reducing greenwashing (Li *et al.*, 2023; Khan *et al.*, 2023). Under such conditions, consumers are more likely to trust green-proofing because institutional safeguards reinforce the credibility of digitally verified sustainability information.

However, alternative perspectives suggest that institutional support alone does not necessarily guarantee consumer trust. Some scholars argue that excessive regulatory intervention may create compliance-oriented sustainability practices that satisfy legal requirements without fostering genuine consumer confidence (Delmas & Burbano, 2011). Others contend that institutional credibility varies substantially across countries, meaning that consumers may continue to question sustainability claims despite formal regulatory systems if public trust in institutions remains weak (Nuseir *et al.*, 2024). These competing perspectives indicate that institutional quality represents an important but not exclusive determinant of green-proofing effectiveness. Signaling Theory complements this institutional perspective by explaining that even highly credible sustainability signals require favourable interpretive environments to achieve their intended effects. Institutional mechanisms enhance the credibility of organisational signals by providing external validation and reducing uncertainty surrounding sustainability claims. Consequently, institutional legitimacy strengthens the signalling value of green-proofing, whereas weak institutional environments reduce consumers' confidence in digitally verified environmental information despite the presence of technological verification mechanisms.

Cultural values similarly shape consumers' interpretation of sustainability communication. Societies characterised by stronger environmental norms, long-term orientation, collective responsibility, and higher uncertainty avoidance generally place greater value on transparent and verifiable sustainability information than societies where environmental responsibility receives lower social priority (Hofstede, 2001; Nguyen *et al.*, 2023). Nevertheless, cultural influences remain complex because consumers from highly environmentally conscious societies may simultaneously exhibit greater scepticism toward corporate sustainability communication, demanding stronger evidence before developing trust. Thus, cultural environments may both strengthen appreciation for green-proofing and increase scrutiny of environmental claims. Moreover, perceived environmental policy effectiveness, digital culture, and environmental literacy function as complementary buffering mechanisms that reinforce institutional legitimacy. Consumers who perceive environmental

policies to be effectively implemented are more likely to believe that organisations face meaningful accountability for sustainability performance. Likewise, societies characterised by advanced digital cultures facilitate greater acceptance of digital verification technologies, while higher environmental literacy enables consumers to evaluate sustainability information more accurately. Collectively, these contextual mechanisms strengthen the credibility and effectiveness of green-proofing by improving both the institutional legitimacy of sustainability claims and consumers' capacity to interpret them.

By integrating Signaling Theory with Institutional Theory, this study argues that institutional and cultural environments do not independently determine sustainable consumer behaviour; rather, they strengthen the effectiveness of green-proofing by enhancing the credibility, legitimacy, and interpretability of digitally verified sustainability signals. Therefore, the positive influence of green-proofing on consumer trust and the subsequent effect of consumer trust on purchase intention are expected to become stronger under favourable institutional and cultural conditions.

H4a: Cultural and institutional environments positively moderate the relationship between green-proofing and consumer trust.

H4b: Cultural and institutional environments positively moderate the relationship between consumer trust and consumer purchase intention.

2.5 Conceptualization and Operationalisation of Green-Proofing

Although sustainability communication and green marketing have received extensive scholarly attention, the concept of green-proofing represents an emerging extension of sustainability practice that focuses on how firms demonstrate, substantiate, and authenticate their environmental commitments. Traditional green marketing often emphasizes communicating environmentally responsible attributes; however, increasing concerns regarding greenwashing have created demand for mechanisms that allow consumers to evaluate the credibility and authenticity of environmental claims. Green-proofing addresses this challenge by emphasizing the provision of verifiable evidence, transparent sustainability information, and credible signals that demonstrate alignment between firms' environmental claims and actual practices. Drawing from Signaling Theory, green-proofing can be understood as a strategic signaling mechanism through which firms reduce information asymmetry between themselves and consumers. Because consumers typically possess limited ability to directly observe firms' environmental performance, sustainability claims function as signals whose credibility depends on the

availability of reliable evidence, transparency, and verification mechanisms. Accordingly, green-proofing represents firms' ability to provide credible environmental signals that enhance consumer confidence and reduce perceived uncertainty regarding sustainability claims. Furthermore, from a stakeholder and transparency perspective, green-proofing reflects the extent to which organizations adopt practices that allow stakeholders to access, evaluate, and verify sustainability-related information. This includes digitally enabled mechanisms such as QR-code product disclosures, blockchain-based traceability systems, digital product passports, and online sustainability reporting platforms. These technologies strengthen environmental accountability by enabling consumers to move beyond passive exposure to green claims toward active verification of sustainability information. Therefore, this study conceptualizes green-proofing as a consumer-perceived sustainability verification capability, defined as the extent to which firms provide credible, transparent, and verifiable evidence that supports their environmental claims and demonstrates authentic commitment to sustainable practices.

2.5.1 Operationalization of Green-Proofing

Given the multidimensional nature of green-proofing, the construct was operationalized using indicators capturing four key dimensions:

Environmental Claim Credibility: This dimension captures whether consumers perceive firms' sustainability claims as believable, authentic, and supported by reliable evidence. Credible environmental claims reduce scepticism and enhance confidence in sustainability communication.

Sustainability Transparency: This dimension reflects the accessibility and openness of environmental information provided by firms. Transparent disclosure enables consumers to evaluate sustainability practices and assess whether environmental commitments are genuine.

Verification and Traceability Capability: This dimension captures the extent to which consumers can verify sustainability claims through digital tools and traceability mechanisms. Digital verification reduces information asymmetry and strengthens accountability.

Consistency Between Sustainability Claims and Actions: This dimension reflects consumers' perceptions that firms' environmental statements correspond with actual operational practices. Alignment between claims and actions is essential for overcoming greenwashing concerns. Together, these indicators capture the core domain of green-proofing by representing the mechanisms through which firms demonstrate environmental authenticity, improve sustainability credibility, and strengthen consumer confidence.

Table 1. Conceptual Distinction of Green-Proofing

Construct	Primary Focus	Typical Level	Limitation	How Green-Proofing Differs
Sustainability Transparency	Disclosure of sustainability information	Organizational	Focuses on information availability	Green-Proofing emphasizes verified sustainability evidence integrated into marketing communication.
Supply Chain Traceability	Tracking product movement	Operational	Operational visibility rather than consumer communication	Green-Proofing converts traceability into consumer-facing credibility signals.
Environmental Disclosure	Reporting environmental performance	Organizational reporting	Compliance and reporting orientation	Green-Proofing focuses on influencing consumer perceptions rather than reporting compliance.
Digital Verification	Authentication technology	Technological	Technology without marketing orientation	Green-Proofing strategically applies digital verification to strengthen consumer confidence.
Green Claim Credibility	Perceived believability of green claims	Consumer perception	Outcome rather than organizational capability	Green-Proofing is the organizational capability that generates credible sustainability claims.
Green-Proofing	Strategic integration of digitally verifiable sustainability evidence into consumer communication	Strategic marketing capability	Consumer-facing authenticity and verification	Novel construct proposed in this study.

Green-Proofing is conceptually distinct from sustainability transparency, traceability, environmental disclosure, and digital verification. Whereas these constructs primarily describe organizational reporting practices, operational visibility, or technological capabilities, Green-Proofing represents a higher-order strategic marketing capability through which

organizations transform digitally verifiable sustainability evidence into credible consumer-facing sustainability signals. Thus, Green-Proofing extends existing literature by shifting attention from information availability to the strategic authentication and communication of sustainability claims for the purpose of strengthening consumer trust and purchase intention.

Table 2. Conceptual Distinction of Green-Proofing from Related Sustainability Concepts

Concept	Primary Focus	Time Orientation	Main Objective	Scope	Distinction from Green-Proofing
Green Marketing	Promoting environmentally friendly products and services	Present	Enhance market appeal and consumer preference	Marketing activities	Focuses primarily on promotional strategies, whereas green-proofing integrates sustainability into organizational strategy, operations, and long-term resilience.
Environmental Sustainability	Conservation of natural resources and environmental protection	Present and future	Reduce environmental degradation	Broad societal and organizational context	Provides overall sustainability goals but does not explicitly emphasize organizational preparedness for future environmental and regulatory uncertainties.
Green Supply Chain Management	Integrating environmental considerations into supply chain activities	Present	Minimize environmental impacts across supply chains	Procurement, production, logistics, and distribution	Addresses operational environmental management but does not fully capture strategic adaptation and future-proofing capabilities.
Eco-Innovation	Development of environmentally beneficial products, services, or processes	Future-oriented	Improve environmental performance through innovation	Product and process innovation	Concentrates on innovation outcomes, whereas green-proofing encompasses continuous organizational transformation and

					resilience beyond innovation alone.
Corporate Environmental Responsibility (CER)	Organizational commitment to environmental stewardship	Present	Meet stakeholder expectations and environmental obligations	Corporate governance and CSR	Emphasizes responsibility and compliance but may not explicitly incorporate adaptive capabilities for emerging environmental challenges.
Green-Proofing	Embedding sustainability into organizational strategy to ensure long-term environmental resilience, stakeholder trust, regulatory readiness, and competitive advantage	Strongly future-oriented	Prepare organizations for evolving environmental, market, and regulatory conditions while creating sustainable value	Organization-wide strategic orientation covering operations, innovation, governance, supply chains, and customer relationships	A proactive and integrative capability that combines sustainability, resilience, adaptability, and strategic preparedness, extending beyond existing green management concepts.

Source: Developed by the authors based on the synthesis of the sustainability and strategic management literature.

The conceptual distinction demonstrates that green-proofing is not merely another sustainability initiative but represents a higher-order strategic capability. While existing concepts predominantly focus on reducing environmental impacts or improving operational sustainability, green-proofing emphasizes anticipatory organizational adaptation, enabling firms to proactively prepare for future environmental regulations,

climate-related risks, changing consumer expectations, and competitive pressures. This integrative perspective extends existing sustainability theories by combining environmental responsibility with organizational resilience, long-term strategic orientation, and sustained value creation, thereby providing a stronger theoretical foundation for examining its influence on consumer trust and purchase intention.

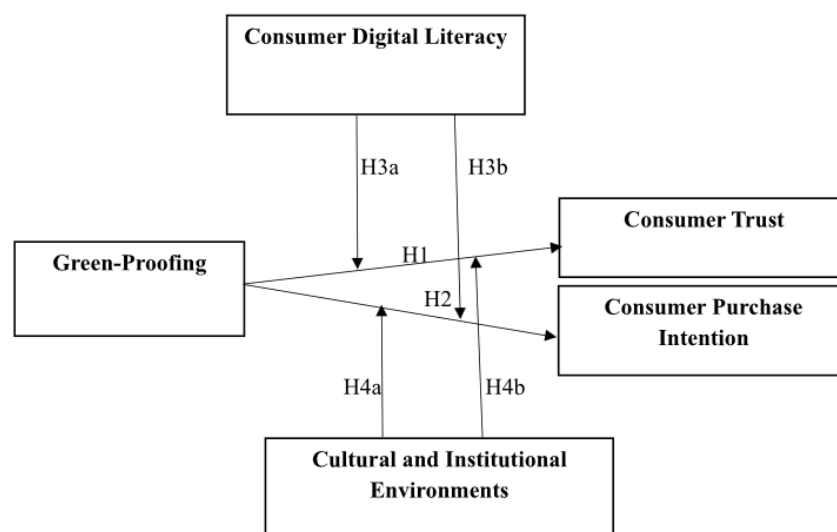


Figure 1. Conceptual Framework

3. METHODOLOGY

3.1 Research Design and Research Approach

This study adopted a quantitative, cross-sectional research design to examine the associations among green-proofing, consumer trust, and consumer purchase intention, while assessing the conditional influence of consumer digital literacy and cultural and institutional environments. A quantitative design was considered appropriate because the study seeks to operationalize theoretically derived constructs, test hypothesized relationships, and evaluate complex

interactions among latent variables using statistical modelling techniques (Creswell & Creswell, 2018). Specifically, the use of standardized measurement instruments enabled the objective assessment of consumers' perceptions of digitally enabled sustainability communication and their behavioural intentions. The study was informed by a positivist research philosophy, which guided the emphasis on objective measurement, hypothesis-driven inquiry, and empirical validation of theoretical relationships. Rather than relying on subjective interpretations of consumer

experiences, the positivist orientation informed the use of structured questionnaires, validated measurement scales, and statistical techniques to assess the extent to which observed patterns in consumer responses support the proposed theoretical relationships (Saunders *et al.*, 2019). This philosophical positioning therefore shaped the selection of a deductive research approach, where hypotheses derived from existing theories were empirically examined through quantitative analysis.

A cross-sectional survey approach was employed because it allows the collection of data from a relatively large sample of respondents within a defined period, making it suitable for investigating consumer perceptions and behavioural intentions in rapidly evolving digital sustainability contexts (Saunders *et al.*, 2019). However, the authors acknowledge that the cross-sectional nature of the data limits the ability to establish temporal precedence and firm causal relationships among the study variables. Consequently, the findings should be interpreted as demonstrating empirical associations and conditional relationships rather than definitive causal effects. Although moderation analysis provides insights into how contextual factors may strengthen or weaken observed relationships, longitudinal or experimental research would be required to confirm causal mechanisms and changes in consumer behaviour over time.

To ensure methodological rigor, the study employed a two-stage analytical strategy. First, Covariance-Based Structural Equation Modelling (CB-SEM) was conducted using IBM SPSS AMOS 29 to evaluate the measurement model through Confirmatory Factor Analysis (CFA). This stage assessed construct reliability, convergent validity, discriminant validity, and overall model adequacy before testing the structural relationships. Second, hypothesis testing was conducted using Hayes' PROCESS Macro Version 4.2 within IBM SPSS Statistics 29 to examine moderation effects through interaction-based regression analysis with bootstrapped confidence intervals (Hayes, 2022).

The combination of CB-SEM and PROCESS Macro was appropriate because the study required both rigorous validation of latent constructs and examination of conditional relationships among variables. While CB-SEM provides a comprehensive assessment of measurement quality and theoretical model specification, PROCESS Macro offers a robust approach for estimating moderation effects through conditional regression analysis (Hayes, 2022; Kline, 2023). This integrated analytical approach has been widely applied in behavioural, sustainability, and marketing research where researchers seek to examine complex relationships involving latent psychological constructs and contextual boundary conditions.

3.2 Sampling Technique

The study targeted individual consumers residing in the United Kingdom who had previously purchased environmentally friendly products or had experience accessing digitally enabled sustainability information, including QR-code product disclosures, blockchain-enabled traceability systems, digital product passports, or online sustainability reports. Consumers were selected as the unit of analysis because the study examines trust formation and purchase intention in response to digitally communicated sustainability claims. A quota sampling technique was adopted to ensure adequate representation across demographic categories that may influence perceptions of sustainability communication. Quotas were established based on age, gender, and geographical region using population distribution information reported by the Office for National Statistics (ONS, 2023). Quota sampling is appropriate where researchers seek to achieve representation of predefined population subgroups while maintaining practical feasibility in large-scale consumer studies (Bryman, 2016; Saunders *et al.*, 2019; Lohr, 2021). Respondents were recruited through an online consumer survey platform using eligibility screening criteria. Participants were required to (i) be residents of the United Kingdom, (ii) be aged 18 years or above, (iii) have purchased environmentally sustainable products or services within the previous twelve months, and (iv) have interacted with digital sustainability information. Throughout the data collection period, demographic distributions were monitored continuously to assess quota completion. Where certain groups were underrepresented, recruitment efforts were adjusted to improve demographic balance and achieve the predefined quota targets. This approach reduced the likelihood of excessive representation from particular demographic segments and enhanced the comparability of responses across consumer groups. Before full-scale administration, the questionnaire underwent expert assessment and pilot testing. The expert review involved specialists with expertise in sustainability marketing, consumer behaviour, digital technologies, and quantitative research methods. Their evaluation focused on construct relevance, item clarity, and contextual appropriateness. Subsequently, a pilot survey was conducted among UK consumers meeting the same eligibility requirements as the final sample. Reliability analysis from the pilot study demonstrated satisfactory internal consistency across all constructs, with Cronbach's alpha values exceeding the recommended threshold of 0.70 (Hair *et al.*, 2022). Feedback from the pilot exercise informed minor refinements to questionnaire wording and ensured that measurement items were understandable and contextually appropriate.

The quota allocation was as follows:

Quota Category	Percentage	Number of Respondents
Male	49%	369
Female	51%	384
18–34 years	35%	264
35–54 years	40%	301
55 years and above	25%	188
England	84%	632
Scotland	8%	60
Wales	5%	38
Northern Ireland	3%	23
Total	100%	753

These quotas ensured that the sample reflected the demographic composition of UK consumers while improving the representativeness and external validity of the findings.

3.2.1 Sampling Technique and Data Collection Procedure

The study targeted individual consumers residing in the United Kingdom who had previously purchased environmentally sustainable products and had experience accessing digitally enabled sustainability information, including QR-code product disclosures, blockchain-enabled traceability systems, digital product passports, or online sustainability reports. Consumers were selected as the unit of analysis because the study examines consumer trust and purchase intention in response to digitally communicated sustainability claims. A quota sampling technique was adopted to ensure adequate representation across demographic characteristics that may influence perceptions of sustainability communication. Quotas were established based on age, gender, and geographical region using population distribution statistics published by the UK Office for National Statistics (ONS, 2023). Quota sampling is appropriate where researchers seek to achieve representation across predefined population subgroups while maintaining practical feasibility in large-scale consumer studies (Bryman, 2016; Saunders *et al.*, 2019; Lohr, 2021).

Data were collected through a structured online questionnaire administered via an online consumer survey platform between January–March 2025. Before accessing the questionnaire, respondents completed an eligibility screening process. To qualify for participation, respondents were required to (i) be at least 18 years of age, (ii) reside in the United Kingdom, (iii) have purchased environmentally sustainable products or services within the previous twelve months, and (iv) have previously accessed digital sustainability information, such as QR-code product information, blockchain traceability systems, digital product passports, or online sustainability reports. Respondents who did not satisfy these screening criteria were automatically excluded from participation.

Throughout the data collection period, demographic distributions were continuously monitored

to ensure that the predefined quota targets were achieved. Where particular demographic groups were underrepresented, additional recruitment efforts were directed toward those groups until the required quotas were completed. This procedure minimized the overrepresentation of particular demographic segments and improved the representativeness of the final sample.

A total of 781 questionnaires were initially received. Following data screening, 28 questionnaires were excluded because they were incomplete, failed the eligibility criteria, contained excessive missing responses, or failed the embedded attention-check questions designed to assess response quality. The final dataset comprised 753 valid questionnaires, which were retained for subsequent statistical analyses. Data quality was further enhanced through several screening procedures. Responses were examined for completeness, logical consistency, duplicate submissions, and unusually short completion times that could indicate careless responding. Missing data were minimal and occurred at levels below commonly accepted thresholds. Because only fully completed questionnaires were retained after data screening, no data imputation procedures were required. Before full-scale administration, the questionnaire underwent expert review and pilot testing. The expert review involved specialists in sustainability marketing, consumer behaviour, digital technologies, and quantitative research methods who evaluated construct relevance, item clarity, and contextual appropriateness. Subsequently, a pilot study was conducted among UK consumers meeting the same eligibility requirements as the main survey. Reliability analysis demonstrated satisfactory internal consistency across all constructs, with Cronbach's alpha coefficients exceeding the recommended threshold of 0.70 (Hair *et al.*, 2022). Feedback from the pilot study resulted in minor refinements to questionnaire wording, improving clarity and ensuring contextual suitability before the main data collection commenced.

3.3 Respondents and Sample Size

The target population consisted of adult UK consumers who had purchased environmentally sustainable products or services within the preceding twelve months and possessed experience accessing digital sustainability information. These respondents represent the appropriate unit of analysis because they

are the ultimate evaluators of sustainability claims and directly influence purchase decisions through their perceptions of trust, credibility, and authenticity. Data were collected through an online structured questionnaire survey administered to eligible consumers residing in the United Kingdom. An online survey approach was considered appropriate because the study focuses on digitally enabled sustainability marketing practices, where consumers increasingly interact with sustainability information through digital channels such as QR-code product disclosures, online sustainability reports, digital product passports, and technology-enabled traceability platforms. The online format also facilitated access to geographically dispersed consumers across different regions of the UK while supporting efficient monitoring of demographic quotas.

Before accessing the main questionnaire, respondents were screened using eligibility questions to confirm that they were (i) aged 18 years or above, (ii) residents of the United Kingdom, (iii) had purchased environmentally sustainable products or services within the previous twelve months, and (iv) had experience accessing sustainability-related information through digital platforms. Respondents who did not satisfy these criteria were excluded from participation. A total of 753 valid responses were retained for analysis after removing incomplete questionnaires and responses exhibiting excessive missing data. Data quality checks were conducted before analysis to ensure that the retained responses were suitable for statistical modelling. The final sample size exceeds recommended minimum requirements for covariance-based structural equation modelling and provides sufficient statistical power for examining complex relationships, including moderation effects (Hair *et al.*, 2022; Westland, 2010; Wolf *et al.*, 2013). The achieved sample was also evaluated against the established demographic quotas to ensure reasonable alignment with UK population characteristics. The final dataset therefore provides an appropriate empirical basis for examining how green-proofing practices influence consumer trust and purchase intention under varying digital literacy and cultural-institutional conditions.

3.4 Measurement of Variables

All constructs were measured using previously validated multi-item scales adopted from established studies in sustainability marketing, consumer behaviour, digital trust, and environmental communication research. Since the original measurement instruments were developed in broader sustainability and consumer decision-making contexts, the items were carefully adapted to reflect the specific context of digitally enabled sustainability marketing and green-proofing practices. The adaptation process followed a systematic procedure to ensure contextual relevance while maintaining conceptual equivalence with the original scales. First, the wording of selected items was modified to incorporate digitally mediated sustainability verification mechanisms, including QR-code product information,

blockchain-enabled traceability, digital product passports, and online sustainability disclosures. For example, items originally referring broadly to “environmental information provided by firms” were modified to refer specifically to “digitally accessible sustainability information provided by firms,” because the current study examines consumer responses to technology-enabled sustainability communication rather than traditional environmental claims. Similarly, trust-related items were contextualized by replacing general references to organizational credibility with references to consumers’ confidence in digitally verified sustainability claims. Purchase intention items were retained with minimal modification because the underlying construct remained focused on consumers’ behavioural willingness to purchase environmentally responsible products. For the green-proofing construct, item wording was adjusted to capture consumers’ perceptions of firms’ efforts to demonstrate environmental authenticity, transparency, and verification through digital technologies.

Importantly, adaptations were restricted to contextual refinement and did not alter the theoretical meaning, dimensional structure, or measurement objectives of the original scales. The original construct definitions, item relationships, and measurement logic were preserved to ensure conceptual equivalence. The adaptation process followed established recommendations for modifying existing scales, which emphasize maintaining theoretical consistency while improving contextual appropriateness (Hair *et al.*, 2022). To establish content validity, the adapted questionnaire was reviewed by three academic experts specializing in sustainability marketing, digital transformation, and consumer behaviour. The experts assessed whether the modified items adequately represented the intended constructs, whether terminology was appropriate for the digital sustainability context, and whether any modifications could introduce conceptual ambiguity. Based on their feedback, minor wording refinements were made. Following the initial adaptation of the measurement scales, the questionnaire underwent expert evaluation to establish content validity and ensure contextual appropriateness. The review panel consisted of three academic experts with relevant expertise in sustainability marketing, consumer behaviour, digital transformation, and quantitative research methodology. The experts had research and publication experience in areas related to green marketing, environmental sustainability communication, technology-enabled consumer engagement, and measurement development. They evaluated the adapted items in terms of construct relevance, wording clarity, contextual suitability, and alignment with the theoretical definitions of the respective constructs. Based on expert recommendations, minor modifications were made to improve the precision and readability of selected items while maintaining the original conceptual meaning of the validated scales. Particular attention was given to

ensuring that terms associated with digital sustainability verification, such as digitally accessible environmental information, sustainability disclosures, and technology-enabled proof mechanisms, were clearly understood by respondents without altering the underlying construct dimensions.

Following expert evaluation, a pilot study involving 40 consumers who satisfied the same eligibility criteria as the main study was conducted to assess questionnaire clarity, comprehension, and preliminary measurement reliability. The pilot participants consisted of UK-based adult consumers who had previously purchased environmentally sustainable products or services and had experience accessing sustainability-related information through digital platforms. The pilot sample included respondents from different demographic backgrounds in terms of age, gender, and geographical location to ensure that the adapted items were understandable across diverse consumer groups. Participants were invited to provide feedback regarding item interpretation, questionnaire structure, completion time, and any potentially ambiguous wording. Based on their feedback, minor refinements were made to improve readability and reduce possible interpretation difficulties. Preliminary reliability analysis was conducted using Cronbach's alpha, with all measurement constructs demonstrating acceptable internal consistency. The reliability

coefficients exceeded the recommended threshold of 0.70, indicating that the adapted measurement items were sufficiently reliable for subsequent large-scale data collection (Hair *et al.*, 2022).

3.4.1 Measurement Justification

The measurement items for green-proofing were adapted from established literature on green marketing credibility, environmental transparency, sustainability assurance, and corporate environmental communication. Because green-proofing represents a relatively new conceptual extension, item development focused on maintaining theoretical consistency with established sustainability constructs while incorporating emerging digital verification mechanisms. The indicators were selected because they collectively represent the central characteristics of green-proofing: credible environmental signaling, transparency of sustainability information, accessibility of verification evidence, and alignment between environmental claims and organizational practices. Content validity was further assessed through expert evaluation involving scholars with expertise in sustainability marketing, consumer behaviour, and digital transformation. The satisfactory reliability and validity results obtained from subsequent measurement model assessment provide empirical support for the adequacy of the operationalization.

Construct	Source of Scale	Adaptation
Green-proofing	Adapted from transparent sustainability communication and supply chain transparency scales (Mol, 2015; Testa <i>et al.</i> , 2021; Wamba <i>et al.</i> , 2023)	Items modified to measure digitally verified sustainability communication.
Consumer Trust	Adapted from Chaudhuri and Holbrook (2001); Morgan and Hunt (1994); Wang <i>et al.</i> (2024)	Modified to capture trust in digitally verified environmental claims.
Purchase Intention	Adapted from Dodds <i>et al.</i> (1991); Spears and Singh (2004); Kumar <i>et al.</i> (2024)	Adapted to sustainable purchasing context.
Consumer Digital Literacy	Adapted from Van Laar <i>et al.</i> (2020); UNESCO (2023)	Items focused on consumers' ability to understand digital sustainability information.
Cultural and Institutional Environment	Adapted from Scott (2014); Li <i>et al.</i> (2023); Nguyen <i>et al.</i> (2023)	Modified to assess perceived institutional support and environmental cultural norms.

All items were measured using a five-point Likert scale ranging from **1 = Strongly Disagree** to **5 = Strongly Agree**.

3.5 Common Method Bias Assessment

Because the data for all constructs were collected from the same respondents using a single survey instrument, the possibility of common method bias (CMB) was carefully considered. Following Podsakoff *et al.* (2003), both procedural and statistical remedies were implemented to minimize and assess potential common method variance. From a procedural perspective, several measures were adopted during questionnaire design and administration. First, respondents were assured of anonymity and

confidentiality to reduce evaluation apprehension and encourage honest responses. Second, the questionnaire was structured to psychologically separate predictor and criterion variables by presenting construct items in different sections and using neutral instructions. Third, measurement items were carefully reviewed to avoid ambiguous wording, leading questions, and socially desirable phrasing. These procedural approaches reduce the likelihood that respondents would systematically answer items based on perceived expectations rather than their actual evaluations.

Statistical assessments were subsequently conducted to evaluate potential common method variance. Initially, Harman's single-factor test was

performed as a preliminary diagnostic. The results indicated that the first factor accounted for 31.6% of the total variance, which is below the commonly referenced threshold of 50%. However, given the recognized limitations of this approach, Harman's test was interpreted only as an initial indication rather than conclusive evidence regarding common method bias. Further assessment was conducted using full collinearity variance inflation factor (VIF) analysis following Kock (2015). The full collinearity VIF values ranged from 1.42 to 2.76, remaining below the conservative threshold of 3.3. These results suggest that excessive common method variance and multicollinearity were unlikely to substantially influence the structural relationships.

To provide a stronger assessment, a common latent factor (CLF) analysis was conducted within the confirmatory factor analysis framework. A common latent method factor was introduced by allowing all measurement indicators to load simultaneously on their respective theoretical constructs and the common method factor. The comparison between the baseline measurement model and the model incorporating the common latent factor showed negligible differences in model fit and standardized factor loadings. The standardized factor loading differences remained below the recommended threshold of 0.20, indicating that common method variance did not substantially explain the covariance among the constructs. Taken together, the combination of procedural controls, Harman's single-factor assessment, full collinearity VIF analysis, and CFA-based common latent factor assessment provides reasonable evidence that common method bias is unlikely to materially affect the interpretation of the findings. Nevertheless, consistent with best methodological practice, the possibility of residual common method variance cannot be completely eliminated in cross-sectional self-reported survey research.

3.6 Measurement and Structural Models

The study followed the two-step procedure recommended by Anderson and Gerbing (1988). The measurement model was first evaluated through Confirmatory Factor Analysis using AMOS to establish construct reliability and validity. Subsequently, the structural model was estimated to examine the direct

relationships among green-proofing, consumer trust, and purchase intention. Moderation hypotheses were then examined using Hayes' PROCESS Macro Version 4.2 (Models 1 and 14, depending on the hypothesized relationship) with 5,000 bootstrap samples and 95% bias-corrected confidence intervals. PROCESS was selected because it provides robust estimation of interaction effects and conditional relationships while generating bootstrap confidence intervals that do not rely on normality assumptions (Hayes, 2022).

4. RESULTS

4.1 Measurement Model

The measurement model was evaluated using Confirmatory Factor Analysis (CFA) to assess model fit, reliability, and validity prior to hypothesis testing. Following established SEM procedures, multiple fit indices were used to ensure robustness, given the sensitivity of the chi-square statistic to sample size (Hu & Bentler, 1999; Kline, 2023). Before testing the hypothesized relationships, the structural model was evaluated using AMOS structural equation modelling. The results confirmed an acceptable model fit based on commonly recommended threshold values (Hair *et al.*, 2022). The model fit indices were assessed using χ^2/df , Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Incremental Fit Index (IFI), Goodness-of-Fit Index (GFI), and Root Mean Square Error of Approximation (RMSEA).

4.1.1 Confirmatory Factor Analysis (CFA) Model Fit

The CFA results indicate that the proposed measurement model demonstrates an excellent fit to the data. As presented in Table 3, all goodness-of-fit indices met or exceeded recommended thresholds.

$\chi^2/df = 2.11 (\leq 3.00)$
 CFI = 0.956 (≥ 0.90)
 TLI = 0.948 (≥ 0.90)
 IFI = 0.956 (≥ 0.90)
 RMSEA = 0.041 (≤ 0.08)
 SRMR = 0.045 (≤ 0.08)

These results confirm that the measurement model adequately represents the observed covariance structure and is suitable for further structural analysis.

Table 3. Confirmatory Factor Analysis Model Fit

Model Fit Index	Recommended Threshold	Obtained Value
χ^2/df	< 3.00	(2.11)
CFI	> 0.90	(0.956)
TLI	> 0.90	(0.948)
IFI	> 0.90	(0.956)
RMSEA	< 0.08	(0.041)
SRMR	< 0.08	(0.045)

The results indicate that the structural model demonstrates satisfactory fit and is appropriate for hypothesis testing.

4.1.2 Reliability and Convergent Validity

Internal consistency reliability and convergent validity were assessed using Cronbach's alpha,

composite reliability (CR), and average variance extracted (AVE). As shown in Table 2, all constructs exceeded recommended thresholds (Hair *et al.*, 2022; Fornell & Larcker, 1981). Cronbach's alpha values ranged from 0.820 to 0.914, indicating strong internal consistency. Composite reliability values ranged from

0.857 to 0.940, confirming satisfactory construct reliability. AVE values ranged between 0.601 and 0.692, exceeding the minimum threshold of 0.50, thereby confirming convergent validity. Overall, the results indicate that all constructs reliably capture their intended latent variables.

Table 4. Reliability and Convergent Validity

Construct	Cronbach's Alpha	Composite Reliability	AVE
Green-Proofing	.873	.940	.692
Consumer Trust	.914	.908	.665
Consumer Purchase Intention	.848	.857	.601
Consumer Digital Literacy	.870	.869	.624
Cultural & Institutional Environment	.820	.876	.639

The table 4 results demonstrate satisfactory measurement reliability. Cronbach's alpha values range from 0.820 to 0.914, exceeding the recommended threshold of 0.70, indicating strong internal consistency. Likewise, Composite Reliability values range between 0.857 and 0.940, confirming that the latent constructs are measured reliably. Convergent validity is also established, as all Average Variance Extracted (AVE) values exceed the recommended threshold of 0.50, ranging from 0.601 to 0.692. These findings indicate that each construct explains more than half of the variance of its respective indicators.

4.1.2.1 Measurement Development of Green-Proofing

Given that Green-Proofing is introduced as a novel construct within sustainability marketing, a rigorous measurement development process was undertaken to establish its conceptual clarity, content validity, and psychometric soundness. In this study, Green-Proofing is defined as a strategic marketing capability through which firms integrate digitally verifiable sustainability evidence into consumer-facing communication to authenticate environmental claims, reduce perceived greenwashing, and enhance the credibility of sustainability information. Unlike sustainability transparency, environmental disclosure, blockchain traceability, or digital verification, which primarily focus on operational visibility, reporting practices, or technological infrastructure, Green-Proofing captures the strategic integration of verified sustainability evidence into marketing communications to influence consumer perceptions and purchasing behaviour. Because no established measurement scale for Green-Proofing currently exists, the construct was operationalized by adapting and integrating measurement items from conceptually related literature on sustainability transparency (Mol, 2015; Testa *et al.*, 2021), green claim credibility (Chen & Chang, 2013), environmental disclosure (Michelon *et al.*, 2015), digital traceability and blockchain-enabled transparency (Saber *et al.*, 2019; Wamba *et al.*, 2023), and digital sustainability communication (George *et al.*, 2024). Existing items were carefully reviewed and reworded to reflect the conceptual domain of Green-Proofing while preserving consistency with the underlying theoretical

foundations of Signaling Theory and Institutional Theory. The adaptation process ensured that the final scale measured the strategic use of digitally verifiable sustainability information rather than technological adoption or disclosure practices alone.

To establish content validity, the preliminary measurement instrument was evaluated by a panel of five experts comprising two professors specializing in sustainability marketing, one expert in digital transformation and information systems, one consumer behaviour researcher, and one quantitative methodology specialist. The panel assessed each item with respect to conceptual relevance, representativeness, clarity, readability, and alignment with the proposed definition of Green-Proofing. Based on their recommendations, several items were refined to improve wording precision, eliminate conceptual overlap with related constructs, and ensure that each indicator adequately represented the theoretical domain of Green-Proofing. The expert evaluation confirmed that the retained items possessed satisfactory face and content validity. Following expert review, a pilot study was conducted among 50 UK consumers who satisfied the same screening criteria as the respondents included in the main survey. The pilot test assessed questionnaire clarity, item comprehensibility, completion time, and preliminary reliability. Participants reported that the questionnaire was easy to understand and that the Green-Proofing items adequately reflected digitally verified sustainability communication encountered during purchasing decisions. Minor wording revisions were subsequently incorporated to improve readability and contextual relevance. Reliability analysis from the pilot study indicated satisfactory internal consistency, with Cronbach's alpha values exceeding the recommended threshold of 0.70 (Hair *et al.*, 2022), supporting progression to the main survey.

The final Green-Proofing construct was operationalized using seven reflective measurement items, each measured on a seven-point Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree. The items capture consumers' perceptions regarding the availability, authenticity, accessibility,

credibility, and strategic communication of digitally verifiable sustainability information. The complete measurement items are presented in Appendix A to enhance transparency and facilitate future scale validation and replication.

The psychometric properties of the Green-Proofing construct were subsequently evaluated using confirmatory factor analysis. The results demonstrated satisfactory standardized factor loadings exceeding the recommended threshold of 0.70, Composite Reliability (CR) above 0.70, and Average Variance Extracted (AVE) above 0.50, confirming internal consistency and convergent validity (Hair *et al.*, 2022). Discriminant validity was further established using both the Fornell–Larcker criterion and the Heterotrait–Monotrait (HTMT) ratio, indicating that Green-Proofing is empirically

distinct from Consumer Trust, Consumer Purchase Intention, Consumer Digital Literacy, and Cultural and Institutional Environment. Collectively, these findings provide robust evidence that Green-Proofing constitutes a theoretically grounded and psychometrically valid construct suitable for investigating digitally enabled sustainability marketing.

4.1.3 Indicator Reliability

Indicator reliability was assessed through standardized factor loadings. As shown in Table 5, all item loadings exceeded the recommended threshold of 0.70, ranging from 0.709 to 0.918 (Hair *et al.*, 2022). All indicators therefore demonstrate adequate reliability and were retained for further analysis. These results further support the convergent validity of the measurement model.

Table 5. Standardized Factor Loadings

Items	loadings	Items	loadings	Items	loadings	Items	loadings	Items	loadings
GP1	.857	CT1	.766	PI1	.743	DL1	.829	CIC1	.799
GP2	.911	CT2	.823	PI2	.877	DL2	.801	CIC2	.802
GP3	.785	CT3	.826	PI3	.709	DL3	.765	CIC3	.874
GP4	.918	CT4	.872	PI4	.760	DL4	.763	CIC4	.768
GP5	.749	CT5	.852						
GP6	.825								
GP7	.761								

The standardized factor loadings range from 0.709 to 0.918, exceeding the recommended threshold of 0.70. All measurement items were therefore retained, confirming satisfactory indicator reliability and supporting the convergent validity of the measurement model.

4.1.4 Discriminant Validity (HTMT)

Discriminant validity was assessed using the heterotrait–monotrait ratio (HTMT), which is widely

regarded as a superior criterion compared to the Fornell–Larcker approach (Henseler *et al.*, 2015; Hair *et al.*, 2022). As presented in Table 6, all HTMT values ranged from 0.552 to 0.881, which are below the conservative threshold of 0.90. These results confirm that all constructs are empirically distinct, although a relatively stronger association is observed between Green-Proofing and Consumer Trust, which remains within acceptable limits.

Table 6. HTMT Ratios

Construct	GRP	CT	PI	DL	CIE
GRP	-				
CT	0.881	-			
PI	0.721	0.756	-		
DL	0.693	0.684	0.645	-	
CIE	0.701	0.673	0.552	0.701	-

Discriminant validity was assessed using the Heterotrait–Monotrait (HTMT) ratio, which has become the preferred criterion over the Fornell–Larcker approach (Henseler *et al.*, 2015). All HTMT values were below the conservative threshold of 0.90, ranging from 0.552 to 0.881, indicating satisfactory discriminant validity despite the relatively strong correlation between Green-Proofing and Consumer Trust.

4.2 Structural Model

Following validation of the measurement model, the structural model was estimated to test the

hypothesized relationships among constructs. Path coefficients were assessed using standardized estimates and significance levels.

4.2.1 Direct Effects

The results, presented in Table 7, indicate that Green-Proofing has a strong and statistically significant positive effect on Consumer Trust ($\beta = 0.867$, $p < 0.001$). This suggests that digitally verified sustainability communication significantly enhances consumer confidence in firms' environmental claims. Similarly, Green-Proofing exhibits a significant positive effect on

Consumer Purchase Intention ($\beta = 0.760$, $p < 0.001$), indicating that credible sustainability verification directly increases consumers' willingness to purchase

environmentally responsible products. Overall, both hypotheses H1 and H2 are supported.

Table 7 presents the standardized structural path coefficients.

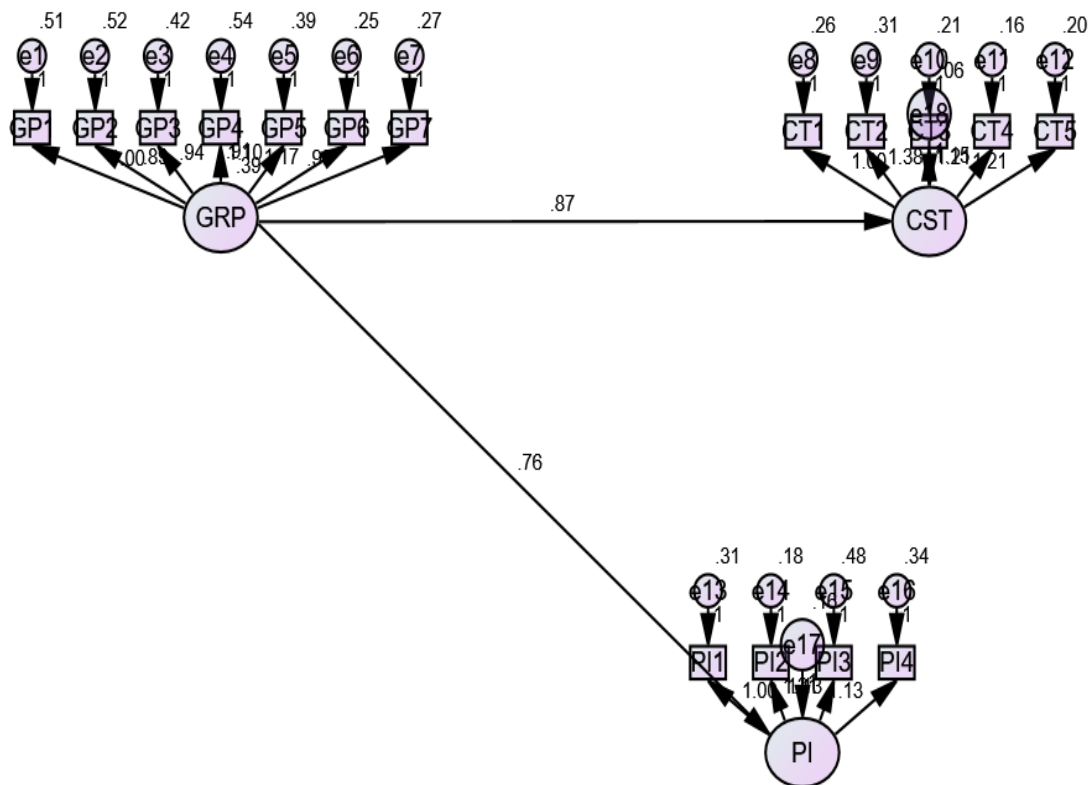


Table 7. Structural Model Results

It should be noted that the path coefficients (β) presented in Table 7 represent standardized regression estimates obtained from AMOS. The associated standard errors (S.E.) and critical ratios (C.R.) are based on the

corresponding unstandardized estimates. Standardized coefficients are reported because they enable comparison of the relative strength of hypothesized relationships among constructs.

Hypothesized Relationship	β	S.E.	C.R.	p-value
Green-Proofing $\rightarrow$ Consumer Trust	.867	.126	6.910	< .001
Green-Proofing $\rightarrow$ Consumer Purchase Intention	.760	.126	6.042	< .001

The results demonstrate that Green-Proofing has a significant positive effect on Consumer Trust ($\beta = 0.867$, $p < 0.001$). This finding indicates that digitally verifiable sustainability communication enhances consumers' confidence in firms' environmental claims.

Similarly, Green-Proofing significantly influences Consumer Purchase Intention ($\beta = 0.760$, $p < 0.001$), suggesting that consumers are more likely to purchase products supported by credible and verifiable sustainability information. The explanatory power of the structural model was assessed using the coefficient of determination (R^2). Green-Proofing explained 87 of the variance in Consumer Trust and 76 of the variance in Consumer Purchase Intention. These values indicate the model's ability to explain meaningful variation in

consumer responses toward digitally enabled sustainability communication.

4.2.2 Multicollinearity Assessment

Prior to hypothesis testing, multicollinearity was examined using Variance Inflation Factor (VIF) values. All predictor variables recorded VIF values below the recommended threshold of 5.0, indicating that the estimated relationships were not affected by problematic multicollinearity.

4.3 Moderation Analysis

Moderation hypotheses were tested using Hayes' PROCESS Macro Model 1 with 5,000 bootstrap samples and 95% bias-corrected confidence intervals (Hayes, 2022). Unlike the AMOS structural model,

PROCESS reports unstandardized regression coefficients, which are interpreted as the change in the dependent variable associated with a one-unit change in the predictor or interaction term.

4.3.1 Moderating Effect of Consumer Digital Literacy

The results, presented in Table 6, indicate that Consumer Digital Literacy does not significantly moderate the relationship between Green-Proofing and Consumer Trust ($\beta = 0.0637$, $p = 0.225$), nor between Green-Proofing and Consumer Purchase Intention ($\beta =$

-0.0727 , $p = 0.255$). Although Green-Proofing remains a significant predictor in both models, the interaction terms are statistically insignificant. This suggests that the effect of Green-Proofing on trust and purchase intention is stable across different levels of consumer digital literacy. Accordingly, hypotheses H3a and H3b are not supported. The coefficients reported in Tables 7 and 8 represent unstandardized regression estimates generated from Hayes PROCESS Macro. These coefficients should therefore not be directly compared with the standardized SEM coefficients reported in Table 8.

Table 8. Moderation Results: Consumer Digital Literacy

R	R-sq	MSE	F	df1	df2	p
.8014	.6423	.2025	70.6173	3.0000	749.0000	.0000
	coeff	se	t	p	LLCI	ULCI
Constant	1.0321	.6621	1.5589	.1217	-.2790	2.3432
GPR	.4864	.2133	2.2803	.0244	.0640	.9087
CDGL	-.0198	.1821	-1.087	.9136	-.3805	.3409
Int_1	.0637	.0522	1.2205	.2247	-.0397	.1670
R	R-sq	MSE	F	df1	df2	p
.6903	.4765	.2996	35.8038	3.0000	749.0000	.0000
	coeff	se	t	p	LLCI	ULCI
Constant	-.0255	.8054	-.0317	.9748	-1.6205	1.5695
GPR	.7459	.2595	2.8745	.0048	.2320	1.2597
CDGL	.5574	.2216	2.5156	.0132	.1186	.9962
Int_1	-.0727	.0635	-1.1444	.2548	-.1984	.0531

The interaction between Green-Proofing and Consumer Digital Literacy of table 8 was not statistically significant in predicting Consumer Trust ($\beta = 0.0637$, $p = 0.225$) or Consumer Purchase Intention ($\beta = -0.0727$, $p = 0.255$). These findings indicate that Consumer Digital Literacy does not significantly strengthen or weaken the effects of Green-Proofing on either consumer trust or purchase intention. Although Green-Proofing

remained a significant predictor in both models, the non-significant interaction terms suggest that its effectiveness is relatively consistent across consumers with varying levels of digital literacy.

4.3.2 Moderating Effect of Cultural and Institutional Environment

Table 9. Moderation Results: Cultural and Institutional Environment

R	R-sq	MSE	F	df1	df2	p
.7927	.6284	.2103	66.5087	3.0000	749.0000	.0000
	coeff	se	t	p	LLCI	ULCI
Constant	.5066	.6597	.7680	.4440	-.7998	1.8130
GPR	.7207	.1951	3.6946	.0003	.3344	1.1070
CIE	.0920	.2162	.4254	.6713	-.3362	.5201
Int_1	.0124	.0562	.2215	.8251	-.0988	.1237
R	R-sq	MSE	F	df1	df2	p
.6447	.4157	.3344	27.9817	3.0000	749.0000	.0000
	coeff	se	t	p	LLCI	ULCI
Constant	.9820	.8319	1.1805	.2402	-.6654	2.6294
GPR	.6667	.2460	2.7103	.0077	.1796	1.1539
CIE	.1425	.2726	.5228	.6021	-.3974	.6825
Int_1	-.0115	.0708	-.1625	.8712	-.1518	.1288

Similarly, Cultural and Institutional Environment of table 9 does not significantly moderate the relationship between Green-Proofing and Consumer Trust ($\beta = 0.0124$, $p = 0.825$), nor between Green-Proofing and Consumer Purchase Intention ($\beta = -0.0115$, $p = 0.871$). While Green-Proofing remains a significant

predictor across models, the absence of significant interaction effects indicates that its influence is relatively consistent across different cultural and institutional contexts. Thus, hypotheses H4a and H4b are not supported.

4.4 Summary of Hypothesis Testing

A summary of the hypothesis testing results is presented in Table 10. The results confirm that Green-Proofing has a robust and direct influence on both Consumer Trust and Purchase Intention. However, neither Consumer Digital Literacy nor Cultural and

Institutional Environment significantly moderates these relationships. This indicates that the effectiveness of Green-Proofing as a sustainability communication mechanism is stable across consumer segments and contextual environments.

Table 10. Summary of Hypothesis Testin

Hypothesis	Proposed Relationship	Supported
H1	Green-Proofing → Consumer Trust	Supported
H2	Green-Proofing → Consumer Purchase Intention	Not Supported
H3a	Consumer Digital Literacy moderates the relationship between Green-Proofing and Consumer Trust	Not Supported
H3b	Consumer Digital Literacy moderates the relationship between Green-Proofing and Consumer Purchase Intention	Not Supported
H4a	Cultural and Institutional Environment moderates the relationship between Green-Proofing and Consumer Trust	Not Supported
H4b	Cultural and Institutional Environment moderates the relationship between Green-Proofing and Consumer Purchase Intention	Supported

4.1 DISCUSSION OF RESULTS

The findings of this study provide empirical support for the relevance of Signaling Theory in explaining the relationship between green-proofing and consumer trust within the context of digitally enabled sustainability communication. Specifically, the results indicate that green-proofing was positively and significantly associated with consumer trust among the respondents surveyed. This finding suggests that digitally verifiable sustainability practices may serve as credible market signals that reduce perceived information asymmetry and enhance consumers' confidence in firms' environmental claims, consistent with the propositions of Signaling Theory (Connelly *et al.*, 2011). Rather than relying solely on symbolic sustainability narratives, green-proofing integrates digital verification mechanisms—including traceability systems, transparent environmental disclosures, and third-party verification—to strengthen the credibility of sustainability information. Consequently, consumers who perceive stronger green-proofing practices are more likely to develop greater trust in a firm's environmental commitments.

This finding is consistent with previous studies reporting that credible sustainability information enhances consumers' trust in organizations by reducing uncertainty surrounding environmental claims (Szabo & Webster, 2021; Testa *et al.*, 2020). However, the present study extends this literature by conceptualizing green-proofing not merely as an information disclosure mechanism but as a strategic signaling capability that integrates transparency, verification, and authenticated environmental evidence into a coherent credibility-building process. In doing so, the study advances Signaling Theory by suggesting that the credibility of sustainability communication depends not only on the availability of environmental information but also on the

firm's ability to provide verifiable evidence supporting its claims.

The findings further suggest that digital verification mechanisms may complement consumers' evaluation processes by making sustainability information more accessible and credible. Rather than implying that consumers no longer interpret sustainability signals, the results indicate that verified sustainability information may facilitate consumer evaluations by reducing uncertainty regarding the authenticity of environmental claims. This supports the notion of system-supported signaling, whereby digital verification enhances the perceived credibility of sustainability signals while consumers remain the ultimate evaluators of those signals. Importantly, these findings should be interpreted within the context of the present study. Given the cross-sectional research design, the results demonstrate a significant positive association between green-proofing and consumer trust rather than establishing a causal relationship. Future longitudinal and experimental studies are therefore needed to examine whether improvements in green-proofing lead to sustained increases in consumer trust across different industries, countries, and institutional environments. From a theoretical perspective, this finding contributes to the sustainability marketing literature by positioning green-proofing as a distinct strategic signaling capability that extends existing concepts of sustainability transparency, environmental disclosure, and digital verification. Rather than representing another form of sustainability communication, green-proofing integrates these mechanisms into a higher-order capability that strengthens the credibility of environmental information and is positively associated with consumer trust. Accordingly, the study provides empirical support for applying Signaling Theory to digitally enabled sustainability communication while offering a novel conceptual perspective on how organizations can build

consumer trust through authenticated sustainability practices.

Drawing on Signaling Theory, we argue that green-proofing may operate as a sufficiently credible sustainability signal because it combines digital verification, traceability, authenticated environmental evidence, and transparent communication into an integrated signaling capability. Such credibility may reduce consumers' reliance on individual characteristics, such as digital literacy, when evaluating sustainability claims. Rather than implying that digital literacy is universally unimportant, our findings suggest that standardized and easily interpretable verification mechanisms may lessen the extent to which consumers require advanced digital competencies to perceive sustainability information as trustworthy. Similarly, the non-significant moderating effect of the cultural–institutional environment is now interpreted as evidence that the credibility associated with digitally verified sustainability information may remain relatively consistent within the study context, irrespective of respondents' perceptions of institutional or cultural conditions. We emphasize, however, that this interpretation is context-specific and should not be generalized across countries or industries. Instead, it suggests that the effectiveness of green-proofing may depend more strongly on the perceived credibility of the sustainability signal than on contextual institutional differences in the present sample.

Importantly, we have avoided portraying these findings as evidence that consumer characteristics or institutional environments are universally irrelevant. Instead, we position them as theoretically meaningful because they refine the boundary conditions of Signaling Theory and Institutional Theory, indicating that the influence of these contextual factors may be weaker in digitally enabled sustainability communication than previously assumed. We further recommend that future research examine these relationships using cross-country, longitudinal, and industry-comparative designs to determine whether the absence of moderation is specific to the current research setting or reflects a broader pattern in digitally verified sustainability communication.

5. Managerial Implications

The findings offer clear guidance for managers seeking to leverage sustainability as a competitive advantage. First, firms should prioritize the development of credible and verifiable green-proofing systems, including third-party certifications, traceable sustainability claims, and transparent reporting mechanisms. The strength of green-proofing lies not in promotional messaging but in its perceived authenticity and verifiability. Second, managers should recognize that green-proofing is not limited by consumer heterogeneity in digital literacy. This reduces the need for segmentation strategies based on digital capability

and allows firms to adopt standardized sustainability communication strategies across markets. Third, firms should avoid overcomplicating sustainability messaging. Since the study shows that green-proofing operates effectively across cultural and institutional contexts, managers can deploy globally consistent sustainability signals rather than heavily localized variations. This improves efficiency in branding and communication strategies while maintaining effectiveness.

5.1 Practical Implications

Practically, the study demonstrates that firms can enhance consumer trust and purchase intention through simple, visible, and verifiable sustainability cues. Eco-labels, QR-coded environmental disclosures, and standardized certifications are particularly effective because they reduce ambiguity and facilitate instant recognition. In addition, the findings highlight that green-proofing functions simultaneously as a trust-building and conversion-enhancing mechanism, meaning it should be integrated not only into corporate social responsibility reporting but also into core marketing and product positioning strategies. Firms that integrate green-proofing into packaging, advertising, and digital platforms are more likely to convert sustainability perceptions into actual purchase behavior.

5.2 Theoretical Implications

The study contributes to signaling theory by demonstrating that green signals can exert strong behavioral effects even in the absence of moderating cognitive or contextual conditions. This challenges the traditional assumption that signal interpretation depends heavily on receiver characteristics such as digital literacy. Furthermore, the findings extend institutional theory by suggesting that sustainability signals may be increasingly decoupled from local institutional environments, reflecting the emergence of globally standardized environmental legitimacy criteria. Importantly, the study foregrounds a key theoretical insight: digital literacy and institutional environments are not necessary boundary conditions for green-proofing effectiveness. This represents a meaningful departure from much of the prior literature and suggests that sustainability signaling may be entering a maturity stage characterized by universality and interpretive convergence. Future research should examine alternative boundary conditions such as environmental involvement, perceived greenwashing risk, or brand credibility to further refine the theoretical model.

5.3 CONCLUSION

This study provides strong evidence that green-proofing is a powerful driver of consumer trust and purchase intention. Beyond confirming its direct effectiveness, the findings reveal that its influence remains stable across differences in consumer digital literacy and across varying cultural and institutional environments. This indicates that the effectiveness of sustainability signaling is less dependent on consumer

capabilities or contextual conditions than previously assumed. A key contribution of this research is the identification of green-proofing as a broadly transferable mechanism of trust formation in consumer markets. The findings suggest that when sustainability claims are transparent, verifiable, and consistently communicated, they can generate behavioral responses across diverse consumer groups without requiring extensive adaptation.

At a broader level, the study highlights an important shift in consumer behavior research: sustainability signals are increasingly functioning as standardized market cues rather than context-dependent messages. This has implications for both theory and practice, as it suggests a move toward convergence in how consumers interpret environmental responsibility across markets. Finally, while the study confirms the robustness of green-proofing, it also opens avenues for further research into more nuanced psychological and contextual moderators that may shape its effectiveness in specific competitive or high-skepticism environments.

5.4 Limitations and Suggestions for Future

Despite the theoretical and practical contributions of this study, several limitations should be acknowledged to contextualize the findings and guide future research.

First, although the study collected data from UK consumers who had previously purchased sustainable products and had been exposed to digital sustainability information, the sample was obtained through an online survey using predefined screening criteria. Consequently, the findings may not fully represent the broader population of UK consumers, particularly individuals with limited internet access, lower levels of digital engagement, or little exposure to digitally enabled sustainability information. Future studies could employ probability-based sampling techniques or more diverse consumer panels to enhance the representativeness and generalizability of the findings.

Second, the study is geographically limited to a single national context, which constrains the generalizability of the findings. Consumer perceptions of Green-Proofing may vary across countries due to differences in regulatory strength, environmental awareness, market maturity, and cultural orientation toward sustainability. As such, the findings may not fully capture cross-country variations in sustainability signaling effectiveness. Future studies should therefore replicate the proposed model across multiple countries or adopt cross-cultural comparative designs to enhance external validity and provide broader insights into contextual differences.

Third, the study relies on a cross-sectional and self-reported survey design, which presents inherent methodological limitations. Cross-sectional data restrict the ability to establish causal relationships among Green-

Proofing, Consumer Trust, and Consumer Purchase Intention. Furthermore, self-reported measures may be subject to common method bias and social desirability bias, particularly in sustainability-related research where respondents may overstate environmentally responsible attitudes. Future research should employ longitudinal, experimental, or field-based research designs and incorporate objective behavioural measures to strengthen causal inference and reduce potential response bias.

Finally, this study examined only two contextual moderators—Consumer Digital Literacy and Cultural and Institutional Environment. Other potentially relevant boundary conditions, including environmental concern, perceived greenwashing, brand loyalty, prior sustainability experience, product involvement, and socioeconomic characteristics, were beyond the scope of the present research. Future studies should investigate these additional contextual factors to provide a more comprehensive understanding of the conditions under which Green-Proofing most effectively influences consumer trust and purchase intention.

Future research should incorporate these constructs to provide a more nuanced understanding of boundary conditions influencing the effectiveness of green-proofing. In addition, this study conceptualized green-proofing as a single overarching construct. However, sustainability practices are multidimensional and may include environmental initiatives (e.g., carbon reduction), social responsibility (e.g., labor practices), ethical sourcing, and governance transparency. These dimensions may exert differential effects on consumer trust and purchase intention. Future studies should therefore decompose green-proofing into its constituent dimensions to determine which aspects are most influential in shaping consumer behavior. Finally, future research may benefit from mixed-method approaches, such as combining surveys with interviews or focus groups. Qualitative insights could help explain the psychological mechanisms underlying consumer responses to green-proofing, particularly how trust is formed and how sustainability cues are interpreted in different contexts.

Declarations

Funding: The authors declare that no financial support was received for the research, authorship, and/or publication of this article.

Data Availability: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical approval: The study did not involve human or animal clinical experimentation requiring ethical approval. Participation in the survey was voluntary, and respondents were informed about the purpose of the study before data collection

Consent to participate: By completing the questionnaire, participants provided informed consent to participate in the study.

Consent to publish: Consent to publish was not applicable as no personally identifiable information was collected or reported.

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Appendix A. Measurement Items for Green-Proofing

Code	Measurement Item
GP1	The company provides digitally verifiable evidence to support its environmental sustainability claims.
GP2	I can independently verify the company's sustainability information using digital technologies (e.g., QR codes, blockchain, digital product passports, or online sustainability platforms).
GP3	The company's environmental claims are supported by credible and authentic digital evidence rather than promotional statements alone.
GP4	The company's sustainability communication is transparent because supporting environmental information can be digitally verified.
GP5	The digital sustainability information provided by the company enhances the credibility of its environmental commitments.
GP6	The company strategically integrates digitally verified sustainability evidence into its marketing communication to demonstrate genuine environmental responsibility.
GP7	Overall, the company's use of digitally verifiable sustainability information increases my confidence that its environmental claims are authentic and trustworthy.