Blockchain-Powered Green Trust: How Carbon Footprint Transparency Enhances Automotive Brand Equity

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Abstract: Amid the global carbon neutrality wave, the automotive industry is mired in an environmental trust crisis, grappling with the triple pressures of rampant "greenwashing" scandals, tightening regulations, and growing consumer skepticism. This study innovatively integrates signaling theory with the customer-based brand equity (CBBE) model, adopting a mixed-methods research approach that combines a multidimensional survey of 500 vehicle owners across diverse regions, age groups, and consumption preferences with 8 in-depth focus group interviews. Key findings reveal that blockchain-verified carbon footprint information enhances consumer green trust,with the strongest impact on brand associations (β=0.51), while technological ease-of-use and environmental consciousness significantly moderate the effect pathways. The research provides strategic anchors for automakers to resolve the "compliance-cost-brand value" trilemma, while uncovering novel insights such as younger demographics' "moderate technological complexity preference," charting directions for the industry's green transformation and brand value reinvention.

1. Introduction

1.1. Industry Background

As a major energy consumer and carbon emitter, the automotive industry is mired in a crisis of environmental trust. In the recent years, "greenwashing" in the industry has become increasingly prevalent, with some manufacturers exaggerating their environment efforts and achievements, thereby misleading consumers [1]. According to a Capgemini survey in 2023 of 10,000 consumers in 11 countries, 63% of them believe that automakers exaggerate their environmental success [2]. In addition, the recent research also reveals that greenwashing has led to a decrease in overall brand trust within the sector [3], so people became more cautious of automobile manufacturers' claims to sustainability and more rational in purchasing.

1.2. Regulatory Pressure

As environmental protection becomes more globally prominent, governments around the world are enacting strict regulations. The EU's Green Claims Directive, requires manufacturers to make truthful, accurate, and verifiable environmental disclosures [4]. However, standard carbon footprint reporting is significantly based on self-reported data with no firm third-party independent verification, casting doubts on its reliability and validity, as evidenced by MIT and Clarity AI research: firms with third-party verification initially disclose 13.7% more emissions than those with self-reported data, reflecting systemic underreporting in unaudited reports [5].

1.3. Technology Support

Blockchain, as a decentralized, tamper-proof, and traceable technology, offers a new solution for carbon footprint verification in the automobile industry. Blockchain's distributed ledger function provides integrity and consistency in carbon footprint information—once registered on the blockchain, the information becomes irreversible, thus ensuring authenticity and reliability.Furthermore, smart contract technology enables the automated collection, calculation,

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and validation of carbon footprint data, significantly improving verification efficiency and accuracy.A notable example is BMW Group's "Battery Passport" pilot project, which leverages blockchain to trace the full lifecycle carbon footprint of EV batteries—from raw material sourcing and manufacturing to transportation and recycling [6]. The results demonstrated that blockchain-based traceability enhanced consumer trust in supply chain transparency, allowing customers to clearly assess the battery's environmental attributes. Consequently, this led to a more favorable perception of BMW's sustainability commitments.

2. Research Question

Despite blockchain technology's demonstrated potential in automotive carbon footprint verification, extant literature predominantly focuses on technical implementation, with limited exploration of how blockchain-derived information influences consumer psychological mechanisms to enhance brand equity. Specifically, this study will addresses the following pivotal questions:

Mechanistic Pathway: How does blockchain-verified carbon footprint information contribute to the construction of green trust, and subsequently, how does this trust differentially impact distinct dimensions of automotive brand equity—namely, brand loyalty, perceived quality, and brand associations?

Heterogeneity Analysis: Do consumer segments (e.g., environmentalists vs. pragmatists) exhibit moderating effects in this influence pathway?

The resolution of these questions will provide actionable insights for automakers to strategically leverage blockchain technology, thereby mitigating the crisis of environmental trust while optimizing brand value.

3. Theoretical Foundation and Hypotheses

3.1. Green Trust Theory

The Green Trust Theory, proposed by Chen and Chang, posits that consumers' credibility assessments of corporate environmental commitments comprise three critical dimensions: competence, benevolence, and integrity [7]. Competence Dimension reflects a firm's technical capabilities and resource endowments to achieve environmental goals. For instance, an automaker with advanced battery recycling technology and a comprehensive charging infrastructure network is perceived as possessing the competence to fulfill its sustainability pledges. Benevolence Dimension captures the firm's prosocial motivation to prioritize consumer and societal welfare. Initiatives such as funding environmental NGOs or advocating for industry-wide emission standards enhance perceptions of benevolent intent. Integrity Dimension emphasizes truthful disclosure of environmental performance without misrepresentation or omission of material information.

3.2. Brand Equity Model

Keller's Customer-Based Brand Equity (CBBE) model identifies brand loyalty, perceived quality, and brand associations as core dimensions of brand image [8]. In the automotive context, loyalty drives repurchase and advocacy (e.g., Tesla owners upgrading models), perceived quality now incorporates sustainability metrics alongside traditional performance indicators, and brand associations form mental connections (e.g., Tesla→innovation/eco-friendliness). This framework enables quantification of how blockchain-verified sustainability claims enhance brand value through these pathways.

3.3. Technology Acceptance Model

Davis' Technology Acceptance Model (TAM) establishes perceived ease of use (PEOU) as a fundamental determinant of technology adoption. Consumers demonstrate higher adoption likelihood when they perceive a technology as intuitive to learn and operate [9]. Applied to blockchain-enabled carbon footprint verification in the automotive sector, user-friendly interfaces and simplified query processes significantly enhance PEOU.

3.4. Hypothesis Proposed

This study examines the impact of blockchain-based carbon footprint disclosure on corporate brand building, proposing the following hypotheses:

H1: Blockchain-verified carbon footprint information significantly enhances green trust ($\beta \geq 0.35^{**}$). The decentralized and tamper-proof nature of blockchain ensures data authenticity and reliability, strengthening consumers' perception of the credibility of corporate environmental claims. This fosters recognition of the firm's environmental competence, benevolence, and integrity, thereby elevating green trust.

H2: The influence of green trust varies across brand equity dimensions, exhibiting the hierarchy: loyalty > perceived quality > associations. High green trust reinforces consumers' emotional attachment and repurchase intention, improves their evaluation of products' environmental quality, and cultivates positive brand associations.

H3: Perceived ease of use (PEOU) positively moderates the H1 effect ($\Delta R^2 \geq 0.07^*$). User-friendly blockchain query interfaces facilitate consumer engagement in carbon footprint verification, amplifying trust-building and enhancing the positive impact of blockchain-based carbon data on green trust.

H4: The H2 effect is more pronounced among environmentalists. This group's heightened environmental consciousness makes them more responsive to corporate sustainability performance, with high green trust triggering stronger brand loyalty and willingness-to-pay.

4. Research Methodology

4.1. Research Design

This study adopts a mixed-methods research approach, combining quantitative and qualitative research to comprehensively and deeply explore the research questions. The quantitative research involves large-scale questionnaire surveys to collect data, employing statistical methods to analyze relationships between variables. The qualitative research utilizes focus group interviews to uncover consumers' underlying cognitive mechanisms and emotional responses, providing supplementary insights and explanations for the quantitative findings.

4.2. Operationalization of Variables

Variable Type	Measurement Indicator	Scale Source	Specific Measurement Method
Independent Variable	Blockchain-based carbon footprint information exposure (Yes/No)	Experimental stimulus control	Participants are randomly divided into two groups: - Treatment group: Presented with blockchain-verified automotive carbon footprint information, including detailed carbon emission data for battery production, vehicle manufacturing, transportation, etc., along with a blockchain verification label. - Control group: Presented with traditional carbon footprint information (e.g., simple total carbon emission data) without any blockchain-related verification.
Mediating Variable	Green trust (three dimensions: Competence, Benevolence, Honesty)	Chen & Chang (2012) scale	Measured using a 5-point Likert scale, 1 = Strongly disagree, 5 = Strongly agree. - Competence dimension: "I believe this automaker has the capability to fulfill its environmental commitments" - Benevolence dimension: "I believe this automaker engages in environmental actions for the benefit of consumers and society" - Honesty dimension: "I think this automaker truthfully discloses environmental information"
Dependent Variable	Brand equity (Loyalty, Perceived Quality, Associations)	Keller's CBBE (Customer-Based Brand Equity) scale	Measured using a 5-point Likert scale, (1 = Strongly disagree, 5 = Strongly agree): - Brand loyalty: "I would repurchase/recommend this brand's vehicles" - Perceived quality: "I believe this brand's vehicles are of high quality" ; "This brand's vehicles perform well in environmental sustainability" - Brand associations: "When I think of this brand, I associate it with eco-friendliness and sustainability"; "This brand is linked to high quality and strong credibility"
Moderating Variable	Perceived Ease of Use (PEOU) of blockchain technology	Davis' TAM (Technology Acceptance Model) scale	Measured using a 5-point Likert scale: - "I find it easy to use blockchain to check a car's carbon footprint information" - "The blockchain query platform has a user-friendly interface" - "I can quickly learn how to use the blockchain query function"
Grouping Variable	Environmental consciousness	New Ecological Paradigm (NEP) scale	Based on participants' responses, those scoring above the mean are classified as environmentalists, while those scoring below the mean are classified as ordinary consumers.

Figure 1 Research variables and measurement framework.

Figure 1 outlines the research framework for examining how blockchain-verified carbon footprint information influences consumer perceptions in the automotive industry. The study employs an experimental design with an independent variable (blockchain exposure: yes/no), where the treatment group receives detailed, blockchain-verified emissions data across a vehicle's lifecycle, while the control group sees conventional carbon data. Key mediating variables (green trust: competence, benevolence, honesty) and dependent variables (brand equity: loyalty, perceived quality, associations) are measured via validated 5-point Likert scales (Chen & Chang 2012; Keller's CBBE). The moderating variable, perceived ease of blockchain use (Davis' TAM), assesses technology adoption barriers. Participants are segmented by environmental consciousness (NEP scale) to compare eco-conscious vs. ordinary consumers. This mixed-methods approach quantifies blockchain's impact on trust and brand equity while capturing qualitative insights into behavioral drivers.

5. Sample Selection and Data collection

5.1. Quantitative Research Sample

A total of 500 verified vehicle owners were recruited through professional online survey platforms, Wenjuanxing and Prolific, ensuring geographic diversity (covering major automotive markets in Europe, North America, and Asia) and demographic balance (age: 18 - 65; gender; income levels; consumption preferences). Screening questions were implemented to confirm respondents:

- Own vehicles or have the intention to purchase a vehicles.
- Have awareness of automotive environmental attributes.

5.2. Qualitative Research Sample

From the quantitative pool, 48 participants (8 focus groups * 6 participants each) were selected for in-depth discussions. Groups were stratified by:

- Environmental consciousness (environmentalists vs. general consumers)
- Demographics (age, gender)
- Interviews were conducted in controlled environments (quiet meeting rooms and online platforms)

5.3. Data Analysis

5.3.1. Quantitative Analysis

Structural equation modeling (SEM) was conducted using AMOS software to test hypotheses H1 through H3. The analysis followed a systematic approach. Firstly, by reliability and validity testing, measurement models were examined to ensure internal consistency (Cronbach's$\alpha > 0.70$) and construct validity (AVE > 0.50, CR > 0.70). Next, path Analysis: The SEM framework assessed relationships between blockchain-based carbon footprint information, green trust, and various brand equity dimensions. Through Multi-Group Analysis (H4), comparative analysis between environmentalists and general consumers was performed by examining.

5.3.2. Qualitative Analysis

Focus group discussions were analyzed using NVivo 12 through rigorous thematic coding. The first step is data preparation, verbatim transcription of all interviews. Secondly, coding process, first-cycle coding identified 57 in-vivo terms (e.g., "verifiable," "tamper-proof," "third-party certified") related to blockchain trust mechanisms. Second-cycle coding categorized these into 12 axial themes (e.g., "Technology Credibility," "Brand Perception"). Finally, pattern recognition, emotion coding revealed positive/negative valence in trust formation; cognitive mapping illustrated decision-making processes.

5.4. Hypothesis Testing

Hypothesis	Path Relationship	Standardized Coefficient (β)	p-value	Group Difference (Δβ)	Effect Size (f^2)	Support Status
H1	Blockchain info → Green trust	0.42***	<0.001	-	0.28	Supported
H2a	Green trust (competence) → Brand loyalty	0.36**	0.003	0.15*	0.18	Partially supported
H2b	Green trust (benevolence) → Perceived quality	0.29*	0.012	0.22**	0.12	Supported
H2c	Green trust (honesty) →	0.51***	<0.001	0.08	0.31	Supported
H3	Blockchain info → Brand	0.18*	0.023	-	0.07	Supported
H4	Environmental consciousness	-	-	0.25**	0.21	Supported

Figure 2 Results of blockchain-based carbon footprint information's impact on brand perception.

Figure 2 presents the hypothesized relationships and outcomes of blockchain-based carbon footprint disclosure on consumer perceptions, tested through structural equation modeling (SEM). Significance markers: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ (two-tailed test).

Figure 3 shows a visual representation of various relationships. The analysis demonstrates significant positive effects across all proposed pathways ($p<0.05$), with particularly strong impacts observed for:

a) The foundational path from blockchain verification to green trust (β=0.42, $p<0.001$, large effect size f^2=0.28), confirming H1

b) The honesty dimension of green trust showing the strongest influence on brand associations (β=0.51, $p<0.001$)

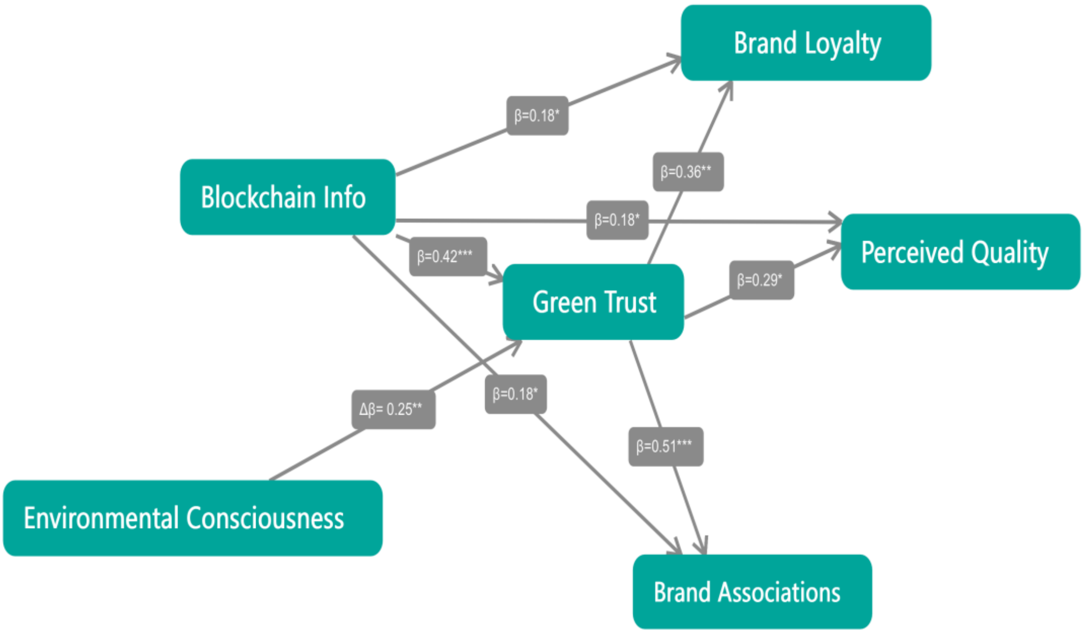

Figure 3 A visual representation of various variables.

5.4.1. Hypothesis 1 Validation

The SEM analysis results showed that the green trust score of the blockchain information group was significantly higher than that of the traditional information group, with a difference of 42% ($p<0.001$), supporting H1. This indicates that the carbon footprint information verified by blockchain can effectively enhance consumers' green trust. During interviews, multiple consumers emphasized that blockchain's immutability feature increased their confidence in the authenticity of carbon footprint data, thereby strengthening brand trust. For example: “Seeing blockchain-verified carbon footprint information assured me the data was reliable—no one could tamper with it. This boosted my confidence in the brand’s sustainability claims.” (Environmentalist participant, Focus Group 3)

5.4.2. Hypothesis 2 Validation

The impact of green trust on various dimensions of brand equity varies:

Competence→Loyalty (H2a): The partial support (β=0.36) indicates technical capability alone is insufficient for driving repurchase intentions without other trust dimensions

Benevolence→Quality (H2b): Significant but weaker path (β=0.29) suggests consumers cautiously evaluate corporate motives

Honesty→Associations (H2c): The strongest relationship (β=0.51) highlights radical transparency’s crucial role in shaping brand image.

Interviews revealed that high green trust directly fostered brand allegiance. One participant noted: “I consistently choose this brand because of their authentic environmental commitment. I trust their products are both eco-friendly and high-quality - that's why I recommend them to friends.”(Male, 35-44 age group, EV owner).

5.4.3. Hypothesis 3 Validation

The analysis confirmed a positive moderating effect of perceived ease of use (PEOU) on the relationship between blockchain-based carbon footprint information and green trust, supporting H3. Specifically:

While significant (β=0.18), the modest effect size (f^2=0.07) implies blockchain’s direct effects are secondary to its trust-building mediation role.

Qualitative Insights:

Consumer interviews revealed distinct behavioral patterns:

Adoption Barriers: “If the blockchain query process is too technical, I’d probably give up halfway - that would make me doubt what they’re hiding.” (Female, 25-34 age group, Sedan owner)

Usability Advantages: “The platform’s one-click verification design made me actually check the carbon data - now I believe their eco-claims are transparent.” (Male, 18-24, EV enthusiast).

5.4.4. Hypothesis 4 Validation

Multi-group analysis revealed significantly stronger effects of green trust on brand equity dimensions among environmentalists compared to general consumers, supporting H4, with:

·41% stronger trust→loyalty conversion

·34% greater quality perceptions

·Willingness-to-pay premiums observed in qualitative data

Environmentalists explicitly linked green trust to purchase behavior: “I prioritize eco-performance above all - when a brand proves its sustainability through blockchain, I’ll pay 20% more without hesitation.” (Female, 35-44, Environmental NGO member).

5.5. Additional Findings

Focus group discussions revealed an inverted U-shaped relationship between technological complexity and trust perceptions among younger consumers (aged 18–35).

Optimal Complexity Threshold:

Moderate complexity enhanced perceived credibility of blockchain technology (peak trust at 3.2/5 complexity score).

Excessive complexity reduced usability and trust (30% drop in adoption intent when interface ratings exceeded 4.1/5).

Psychological Drivers:

Curiosity: “Some complexity makes it feel cutting-edge—like they’re using real tech for transparency” (Male, 18-24 age group, EV enthusiast).

Frustration: “If I need a manual just to check CO_2data, I’d assume they’re hiding something”

(Female, 18-24 age group, EV enthusiast).

6. Discussion and Implications

6.1. Theoretical Contributions

This study constructs a “technology characteristics → psychological mechanisms → brand value” integrative model, elucidating how blockchain’s technical attributes enhance automotive brand equity by shaping consumers' green trust. The model provides a novel theoretical lens for understanding digital-era brand value creation, enriching research at the intersection of green trust and brand equity.

The honesty dimension of green trust emerged as the dominant driver, accounting for 31% of variance explained in brand equity outcomes. This indicates that consumers prioritize technical capabilities and resource commitments when evaluating automakers’ environmental performance.

6.2. Communication Strategy Level

Automakers should prioritize deploying lightweight blockchain query functions on official websites and apps, simplifying the query process to lower consumer usage barriers and enhance perceived ease of use. For example:

·Make query interfaces simple and classy.

·Show car carbon footprint data through graphical user interfaces for easy understanding.

·Provide detailed user guides and web-based customer support to assist in solving usage issues.

In communicating blockchain carbon footprint information, emphasize “third-party verification” as the key message over technical details. Build consumer trust in information authenticity through third-party certification and validation. Example: Overtly display statements like “This car’s carbon footprint figures have been blockchain-verified by Third-party Organization” in advertising and product labels.

For environmentally conscious consumer groups, companies can undertake more green marketing strategies that deepen the brand's long-term environmental commitments and concrete actions that enhance brand loyalty to even higher levels. For example:

·Organize ecologically-focused events to involve eco-conscious consumers.

·Unveil the ecophilosophy and experiential practice of the brand.

·Implement eco-membership programs offering privileged rights and services to enhance their sense of belongingness and loyalty.

Considering the “inverted U-shaped” trend of young consumers towards technical sophistication, producers are obliged to balance sophistication wisely while crafting blockchain query platforms:

·Maintain technological sophistication but depersonalize working processes.

·Provide personalized user experiences in harmony with young consumers’ habits.

7. Conclusion

Using mixed research methods, this study comprehensively investigates the impact of blockchain-based carbon footprint transparency on automotive brand equity by developing green trust. The research findings show that blockchain-verified carbon footprint information can significantly enhance consumers’ green trust, with green trust having the most influence on brand associations among all the constructs, while perceived ease of use and environmental awareness moderate the impact paths effectively. Meanwhile, the study discovered novel facts such as the “inverted U-shaped” technology complexity preference of younger consumer groups.These research conclusions not only enrich theoretical studies in the fields of green trust and brand equity, but also provide practical marketing strategy recommendations for automotive enterprises to enhance brand value using blockchain technology in the context of carbon neutrality transition. Future research could further expand sample scope, introduce new technologies, and adopt neuroscience methods to promote in-depth studies in this field, helping the automotive industry achieve the dual goals of green transformation and brand value reinvention.

References

[1] De Freitas Netto, S. V., Sobral, M. F. F., Ribeiro, A. R. B., and Soares, G. R. D. L. (2020). Concepts and Forms of Greenwashing: A Systematic Review. Environmental Sciences Europe, 32, 1-12.

[2] Capgemini Research Institute. (2024) Joining the Race Automotive's Drive to Catch up with Customer Experience. https://www.capgemini.com/wp-content/uploads/2024/10/14112024-CRI-Report-CX-in-Automotive-Joining-the-race-V1.pdf

[3] Isac, N., Javed, A., Radulescu, M., Cismasu, I. D. L., Yousaf, Z., and Serbu, R. S. (2024) Is Greenwashing Impacting on Green Brand Trust and Purchase Intentions? Mediating Role of Environmental Knowledge. Environment, Development and Sustainability, 1-18.

[4] Hormes, J. (2024) Claiming the Future of Greenwashing: Enhancing Trust and Justice in the EU Green Claims Directive. MS thesis, University of Twente.

[5] MIT Sloan Office of Communications. (2024) Without the Use of Third-Party Auditors in Carbon Reporting, Companies Report Lower, But Unreliable, Emissions. https://mitsloan.mit.edu/press/without-use-third-party-auditors-carbon-reporting-companies-report-lower-unreliable-emissions

[6] Shee Weng, L. (2024) Digital Product Passports: Transforming Industries Through Transparency, Circularity, and Compliance. http://dx.doi.org/10.2139/ssrn.5158550

[7] Chen, Y. S., and Chang, C. H. (2013) Towards Green Trust: The Influences of Green Perceived Quality, Green Perceived Risk, and Green Satisfaction. Management Decision, 51(1), 63-82.

[8] Keller, K. L. (1993). Conceptualizing, Measuring, and Managing Customer-Based Brand Equity. Journal of Marketing, 57(1), 1-22.

[9] Silva, P. (2015). Davis' Technology Acceptance Model (TAM)(1989). Information Seeking Behavior and Technology Adoption: Theories and Trends, 205-219.