NOVA SCHOOL OF BUSINESS & ECONOMICS

Blockchain-enabled Carbon Traceability:

Analyzing Its Impact on Firm Performance in the European Retail Sector – Purchasing Behavior

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Abstract

This study examines the impact of BCCT on purchasing behavior in the European retail sector. The results show that BCCT has no significant effect. While BCCT can objectively increase transparency and trust in environmental claims, the actual impact remains limited. The main reasons for this are a lack of consumer knowledge, limited trust in labels, and low interaction with BCCT information. However, perceived transparency and trust act as drivers of purchasing behavior independent of BCCT. These findings suggest that effective consumer education, targeted sustainability communication, and simplified presentation of carbon data are necessary to realize the potential of BCCT.

Keywords: Carbon Traceability, Blockchain, Retail, Consumer Purchasing Behavior, Transparency

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1. Introduction

In 2019, European Commission President Ursula von der Leyen announced Europe's ambition to become the world's first carbon-neutral continent by 2050. Despite the EU's efforts under the European Green Deal (EGD), progress toward this goal has been insufficient. Climate change has caused €145 billion in damages in the EU over the last decade and is expected to increase significantly in the coming years (European Commission 2022a). To combat this, greenhouse gas (GHG) emissions must be reduced considerably.

However, one industry expert interviewed for this thesis emphasizes, *"You can't improve what you can't measure"* (I7). This highlights a critical challenge: most businesses lack a basic understanding of their emission levels, particularly Scope 3 emissions (Alves, Vieira, and Partyka 2023; Yavari et al. 2023). These include all indirect emissions beyond a company's direct control - such as those from suppliers, transport, and product use or disposal – and are challenging to measure due to difficulties in obtaining data, reliance on supply chain (SC) partners, variability in data sources, and complex interdependencies (Hertwich and Wood 2018). Monitoring, reporting, and verifying (MRV) Scope 1 and 2 emissions is more straightforward. Scope 1 covers direct emissions from company-owned sources, and Scope 2 includes indirect emissions from purchased energy, such as electricity or heating (Callahan et al. 2011; Hettler and Graf-Vlachy 2024). Identifying carbon emissions across all three scopes is defined as carbon traceability (ISO 1994). It is a foundational element for addressing regulatory compliance and voluntary sustainability initiatives, enabling full environmental transparency across an organization's value chain (Lee 2012; Kaur et al. 2024).

Under the regulations set by the EGD, specifically the Corporate Sustainability Reporting Directive (CSRD), starting in 2025, companies must disclose their emissions across all three scopes (European Commission 2023a). This is particularly challenging for the retail sector, which faces significant challenges in tracing and reporting carbon emissions due to the complexity of retail

SCs, diverse product portfolios, and especially the dominance of Scope 3 emissions, which account for 98% of total emissions (McKinsey 2024a). As intermediaries between producers and consumers, Europe's retailers play a crucial economic, generating €3.2 trillion in trade and contributing 20% of EU GDP in 2022 (Statista Research Department 2024a; Nolan, Zhang, and Liu 2007; Eurostat 2024). This economic significance underscores the urgency of addressing carbon traceability challenges in the retail sector, which demands innovative methods that enable comprehensive emissions reporting while ensuring financial viability and aligning sustainability strategies with accurate data on carbon footprints (Dhanda, Sarkis, and Dhavale 2022). Blockchain (BC) technology is currently gaining recognition as a tool for managing and tracing carbon footprints, especially Scope 3 emissions, and resolving issues of trust and cooperation among stakeholders (Kadry 2022). Its core features – immutability, decentralized verification, and real-time traceability – can potentially provide a framework for identifying and verifying emissions data across complex SCs (Munir et al. 2022; Huang, Weber, and Matthews 2009). F.e., the U.S. retailer Walmart piloted BC for carbon traceability with mangoes in the U.S. and pork in China, showing its effectiveness. The system increased transparency by tracing emissions data at each stage of the SC, holding suppliers accountable through carbon scorecards, and sharing environmental impact information with consumers (Tan et al. 2018; Sharma and Kumar 2021).

Despite growing interest in BC technology, current literature primarily centers on social sustainability or product origin information through BC, leaving gaps regarding carbon traceability (Liu, Wang, et al. 2023; Fraser and van der Ven 2022; Biswas et al. 2023). However, even within this scope, existing literature predominantly focuses on isolated SC performance, neglecting its broader implications for overall firm performance (Saberi et al. 2019; Cui, Gaur, and Liu 2023). Additionally, the specific impact of Blockchain-enabled carbon traceability (BCCT) on firm performance within the European retail sector and other firm performance dimensions and

synergies remain unexplored (Kamble et al. 2021; Wamba and Queiroz 2022; Carmeli, Gilat, and Waldman 2007). Therefore, this study addresses the following umbrella research question (RQ):

Umbrella RQ: How *does BCCT impact firm performance in the European retail sector?*

To address the umbrella RQ, we adopt a multidimensional approach, integrating theoretical insights from existing literature with empirical findings to explore the dimensions of BCCT - specifically from the SC, purchasing behavior, talent attraction and retention, and stock price perspective - and their impact on firm performance. This study contributes to existing research by offering a more holistic understanding of the factors influencing performance from an intrinsic firm perspective. Furthermore, it provides actionable implications for effective implementation within the European retail sector.

This thesis is structured as follows: Section 2 provides a theoretical foundation for the thesis. Building on this, Section 3 scrutinizes the impact of BCCT on consumers, focusing on its role in shaping purchasing behavior. The study concludes by synthesizing findings, addressing limitations, and suggesting directions for future research, providing a comprehensive and structured examination of this emerging field.

Some sections were excluded to comply with submission requirements.

2. Background

This section sets the groundwork for analyzing BCCT's impact on firm performance. Section 2.1 outlines the regulatory framework, Section 2.2 examines the current state of the art in carbon traceability, Section 2.3 explores carbon traceability in the retail sector, and Section 2.4 explains BC technology.

2.1. Regulatory Framework

As part of the EGD, the CSRD mandates Environmental, Social, and Governance (ESG) reporting for EU and non-EU firms with considerable operations in the EU. Social disclosures emphasize human rights, diversity, and labor practices, while governance requirements target corporate ethics, anti-corruption measures, and the integration of sustainability into strategic decision-making. This study focuses on the Environmental Pillar of the ESG, which addresses climate-related risks, GHG emissions, and resource consumption (LSEG 2024). According to the CSRD, organizations must trace and report their Scope 1, 2, and 3 emissions quarterly, completing over 200 mandatory fields on an EU portal. For the fiscal year 2024, large public-interest entities with over 500 employees must comply with stricter regulations. For the fiscal year 2025**,** the mandate expands to include large companies reaching at least two criteria: more than 250 employees, a net turnover exceeding €40 million, or total assets over €20 million. Listed small and medium-sized enterprises must comply with the reporting requirements starting in fiscal year 2026, but they can delay compliance until 2028 (European Commission 2023a). Non-EU firms must disclose emissions to access the EU market, promoting comprehensive carbon emission data (Perdana and Vielle 2022).

In practice, the stricter regulations pose significant challenges for many companies across Europe, particularly in independently determining the carbon emissions generated by their overseas suppliers. The EU Commission advises businesses to request carbon emission data directly from them. However, this process can be costly and complicated, especially in multi-tiered SCs where data reliability may be difficult to ensure (BDI and DIHK 2024). Therefore, many companies remain unprepared to meet regulatory requirements, which can result in financial penalties and exclusion from the market (De Villiers, La Torre, and Molinari 2022; Lütkehaus et al. 2022).

2.2. Current State of the Art in Carbon Traceability

Implementing a robust carbon traceability system may offer significant advantages for companies navigating the European regulatory landscape. Firms must ensure near real-time, verifiable, and detailed tracing of individual product emissions while safeguarding business confidentiality and proprietary information (Harbich et al. 2021; Heiss et al. 2024). MRV systems are a common tool for this. In the monitoring phase, companies collect activity data, quantifying business operations that generate GHG emissions. These activities are then translated into emission estimates using emission factors, which are standardized, projected coefficients, often derived from databases like those provided by the Intergovernmental Panel on Climate Change (Heiss et al. 2024). Life Cycle Assessment (LCA) is often used in this context. LCA is a systematic method for evaluating the environmental impacts of products, processes, or services across their entire lifecycle, from raw material extraction to disposal (ISO 1997). In the reporting phase, the calculated emissions are compiled into a report, which must adhere to key accounting principles: relevance, accuracy, completeness, consistency, and transparency. These principles aim to enhance the reliability of the data but cannot entirely mitigate the limitations of approximation (WRI and WBCSD 2011). Finally, verification involves a third-party review to confirm the report's compliance with guidelines and regulatory standards (Heiss et al. 2024).

Conventional MRV systems are limited by long, annual reporting cycles and centralized structures that reduce transparency and trustworthiness (European Commission 2023a; European Commission 2023b). Furthermore, the systems often lack sufficient digitization and automation, resulting in higher costs, increased errors, and inefficiencies (World Bank 2022).

2.3. Carbon Traceability in the Retail Industry

As mentioned before, this thesis focuses on the retail industry, which includes all activities involved in providing goods or services directly to end consumers for personal and non-business objectives. These activities can occur in physical stores, online platforms, or other formats. Given the large share of indirect emissions in retail paired with its vast reach and impact, the sector holds considerable potential to drive large-scale environmental improvements by employing cutting-edge carbon tracing methods (McKinsey 2024a; Ferreira et al. 2019).

However, retail SCs differ from other industries in several ways, making carbon emission traceability more challenging. Retail SCs are inherently more complex than other industries due to the larger and more diverse network of suppliers that retailers must manage (Ge et al. 2019). This diversity arises from a wide product range sourced from various regions and production stages, in contrast to manufacturers who often operate within more streamlined and vertically integrated SCs. Additionally, retail SCs tend to be highly dynamic, as retailers frequently adjust their supplier base to respond to shifts in consumer demand, cost pressures, or seasonal variations. This dynamic nature further complicates establishing and maintaining consistent carbon traceability systems across the SC (Serdarasan 2013). Fragmented data-sharing systems exacerbate these challenges, as multi-level SC stakeholders use inconsistent standards, resulting in incomplete data. Process standardization, regional differences, language barriers, and infrastructure accessibility further complicate carbon traceability in the retail sector (Cura, Jain, and Niinimäki 2022; Stenzel and Waichman 2023).

2.4. Blockchain

In recent years, BC has gained significant attention for being an effective tool for tracing information along value chains and addressing the retail challenges mentioned above (Dong et al.

2023). BC can add significant value to businesses by providing secure transaction verification, reducing costs by eliminating intermediaries and improving efficiency by minimizing delays (Nowiński and Kozma 2017). The growing importance of BC is reflected in its rapid rise in economic significance. While investment in BC reached $800 million in 2014-2015, its projected business value is expected to grow to $3.1 trillion by 2030 - comparable to the current GDP of the entire African continent (McKinsey 2016; Gartner 2022; Statista 2024).

2.4.1. Blockchain Definition and Evolution

According to Tabatabaei, Vitenberg, and Veeraragavan (2023, p.3), the "term of 'Blockchain' generally refers to a paradigm for maintaining information in a distributed system that is characterized by a number of properties." The basic idea behind BC dates back to the 1980s when David Chaum introduced the blind signature. This cryptographic method that enabled anonymous payments by preventing third parties from identifying details such as the payee, amount, or timing of the transaction (Chaum 1983). BC first gained widespread attention in 2008 with the creation of Bitcoin, the first cryptocurrency to showcase BC as a decentralized system (Nakamoto, 2008). Nowadays, BC's practical application extends beyond Bitcoin (Nagar and Manoharan 2022). Specifically, Gurtu and Johny (2019) highlight that BC transitioned from its original use of secure money transactions into becoming a key element in a growing network of new technologies such as artificial intelligence (AI) and Internet of Things (IoT).

2.4.2. Blockchain Characteristics

BC is characterized by its immutability, meaning that it cannot be changed once data is recorded. It operates on a decentralized model that removes the reliance on third-party intermediaries like banks. Transparency is ensured since transactions are securely recorded on a peer-to-peer network, which typically maintains an accessible and transparent ledger. Consensus and advanced

encryption algorithms guarantee that data remains consistent and protected across the network (Capocasale, Gotta, and Perboli 2023; Tripathi, Ahad, and Casalino 2023). For this reason, BC is often referred to as distributed ledger technology (Hilary 2022). Furthermore, it enables rapid validation and permanent transaction recording, improving security and traceability. Users maintain pseudonymity through randomly generated addresses, while each transaction is linked to an unused previous one, enabling effective fraud detection and tracking through time-stamped, verifiable records (Capocasale, Gotta, and Perboli 2023; Tripathi, Ahad, and Casalino 2023).

2.4.3. Blockchain Workflow

BCs consist of sequentially linked data blocks. When a user initiates a transaction, it is sent to the network for validation, ensuring system integrity and security (Vaigandla et al. 2023). Once validated, the transaction is added to a new block, which is cryptographically linked to the previous block, forming an immutable chain. The first block, the genesis block, does not reference a predecessor (Tripathi, Ahad, and Casalino 2023; Vaigandla et al. 2023). Transactions are secured through digital signatures, with users generating signatures using their private keys, while public keys serve as verifiable addresses for verification. These mechanisms ensure the authenticity and immutability of transactions, strengthening BC security (Rajasekaran, Azees, and Al-Turjman 2022). Each block within a BC contains a header, which includes essential metadata like timestamps and cryptographic hashes linking it to previous blocks and a body that records verified transactions. These components together ensure transparency, security, and resistance to tampering (Dong et al. 2023).

2.4.4. Consensus Mechanism

Decisions in BCs are made through consensus mechanisms, which describe a process by which nodes in a BC network collectively verify transactions and determine the order in which they are recorded on the BC (Nagar and Manoharan 2022).

Proof-of-Work (PoW). In BC networks like Bitcoin, the PoW consensus mechanism relies on miners to perform complex computational puzzles to validate transactions and create new blocks, securing the network through energy-intensive competition (Nagar and Manoharan 2022).

Proof-of-Stake (PoS). PoS represents an alternative BC validation approach, where network participants secure the right to verify transactions by depositing and temporarily locking their cryptocurrency. Validator selection is weighted by the size of their financial stake, encouraging network participants to maintain a significant, committed investment in the BC ecosystem. It is substantially less energy-intensive than PoW (Nguyen et al. 2019).

2.4.5. Types of Blockchain

Namasudra and Akkaya (2023) state that there are three types of BCs, namely public or permissionless, private or permission, and consortium. Vaigandla et al.'s (2023) research highlight hybrid BC as a fourth major type.

Public or permissionless BCs. Public or permissionless BCs, like Bitcoin, are decentralized, allowing participants to join freely without approval. They prioritize transparency and security but often face slower transaction speeds due to extensive verification processes (Vaigandla et al. 2023).

Private BCs. Private BCs, in contrast, operate within closed, centrally controlled networks where participants and rules are pre-approved. These BCs offer faster transactions and scalability but sacrifice decentralization and security (Dong et al. 2023; Vaigandla et al. 2023; Namasudra and Akkaya 2023).

Hybrid BCs. Hybrid BCs merge features of public and private BCs, offering controlled data visibility while ensuring transaction transparency through Smart Contracts. They provide flexibility, balancing privacy with transparency (Vaigandla et al. 2023).

Consortium BCs. Lastly, Consortium BCs enable multiple stakeholders to interact within a semi-centralized network, thereby maintaining participant privacy while facilitating efficient, transparent value chain interactions. Their unique architecture allows for accelerated transaction processing and collaborative monitoring, making them well-suited for complex, multi-stakeholder industries requiring robust, privacy-preserving data exchange (Vaigandla et al. 2023; Namasudra and Akkaya 2023). This structure represents a potential approach for retailers and carbon traceability, offering a strategic balance between decentralization and controlled collaboration.

2.4.6. Smart Contracts

Smart Contracts can be a transformative tool within specific BC ecosystems. They are self-executing programs that automatically enforce agreements when pre-defined conditions are met. Unlike traditional paper contracts that require notarization, Smart Contracts operate autonomously through code, eliminating the need for intermediaries to monitor transactions. The contract is executed only when all parties meet the specified requirements, making transactions faster, safer, and more cost-effective while ensuring accuracy and trustworthiness. However, these automated contracts are conspicuously absent from platforms like Bitcoin, demonstrating that their functionality is application-dependent (Bao et al. 2021; Nagar and Manoharan 2022).

2.4.7. Other Technologies

Notably, other technologies have been extensively researched in the context of BCCT.

IoT. IoT is a network of physical devices equipped with sensors, communication technologies, and processing units that can interact with each other and online services. These interconnected "smart"

devices enable real-time data exchange and remote monitoring in applications ranging from home automation to industrial systems and monitoring carbon emissions within SCs. IoT devices typically integrate sensors to collect data, communication transceivers to transmit information, and microcontrollers to process and manage interactions in real-time, enabling sophisticated, automated functionality across multiple industries (Fraga-Lamas et al. 2016; Lee and Chung 2011).

AI. AI adds intelligence to machines, enabling them to gather information, process complex data sets, and make autonomous decisions. While AI systems often require training, they can analyze and interpret data, such as carbon emissions, independently. When connected to IoT, AI processes data collected by IoT nodes and transfers it to cloud platforms for advanced analysis. The system then generates insights, makes decisions, and communicates processed results to specific users or devices within the network, creating a sophisticated, adaptive technology ecosystem (Fraga-Lamas, Lopes, and Fernández-Caramés 2021; Schuetz and Venkatesh 2020).

However, while both technologies offer the potential to complement emissions tracing, this study concentrates specifically on BC.

To summarize, BC's core characteristics could be translated into an effective tool for tracing carbon emissions if the necessary information is uploaded by every player along the SC. Ultimately, this could support the development of a green SC by providing transparency from production to final consumption (Zhao et al. 2022; Wang, Wang, and Abareshi 2020). Notably, the technical implementation is not within the scope of this thesis.

Some sections were excluded to comply with submission requirements.

3. Purchasing Behavior

We will now shift our focus to the consumer-centric view that more and more companies are implementing (Esper et al. 2020). In recent years, consumer demand for sustainable products has grown significantly, accounting for nearly one-third of retail growth and capturing 18.5% of the market share in 2023 (NYU Stern 2023). This shift highlights consumers' growing priority on environmental sustainability, especially reducing GHG emissions, which is one of the top features for which they are willing to pay a premium (McKinsey 2021). However, this demand has also intensified concerns about greenwashing. Key factors undermining the credibility of ecolabels include consumer unawareness, distrust in certifications, the prevalence of counterfeit ecolabels, and insufficient monitoring mechanisms (Hoyer, MacInnis, and Pieters 2012).

In response, traceability technologies, especially BC, have emerged as promising tools to provide transparency and build consumer trust. Major retailers like Carrefour have recognized their role as intermediaries between producers and consumers, positioning them to drive sustainable development by influencing practices at both ends of the value chain (Ruiz-Real et al. 2018).

Despite the promising potential of BC technology to enhance transparency, research has primarily focused on its impact on the SC rather than the consumer viewpoint (Liu, Ma, et al. 2023; Guo et al. 2024). However, the effect on consumer perceptions and purchase decisions is crucial to understanding the value of BCCT for a retailer’s performance. Existing studies that address consumer perspectives primarily emphasize product origin or social sustainability but often overlook verified carbon data - a critical factor in establishing transparency and fostering trust in sustainability claims (Liu, Wang, et al. 2023; Singh and Sharma 2023; Ferreira Da Silva and Moro 2021). Others evaluate carbon disclosure but do not assess whether the enabling technology, f.e., BC, has an impact (Sodhi and Tang 2019; Borghei 2021). Moreover, the impact on consumers'

purchasing intentions has not been thoroughly examined, particularly in the European retail sector. Consequently, the impact of BC as a carbon tracing technology on consumers remains uncertain. This leads to the following RQ:

RQ$_2$: *Does BCCT impact consumers' purchasing behavior in the European retail sector?*

To answer RQ$_2$, this part of the thesis examines explicitly its impact through the mediators of perceived transparency and consumer trust.

3.1. Literature Review

This section provides a foundation for the study by reviewing relevant prior research and formulating hypotheses that address RQ$_2$.

3.1.1. Carbon Disclosure

Global consumer trends indicate that environmental sustainability will control retail market dynamics in the foreseeable future (Singh and Sharma 2023). Consumers increasingly demand information about carbon emissions and prefer low-carbon products when making purchase decisions (Ji, Zhang, and Yang 2017). Therefore, the importance of environmental disclosure is gaining recognition as businesses face increasing pressure to ensure transparency, not only in annual sustainability reports but also at the product level (Peters and Romi 2014; Sodhi and Tang 2019). Although studies have shown that disclosing product origin information can improve consumers' image of the retailer, many companies fail to recognize the value of such disclosure (Sodhi and Tang 2019). Nevertheless, some companies, such as the multinational luxury group Kering goal for 2025, have already recognized its potential by aiming to have full traceability of all primary raw materials by 2025, with a few subsidiaries already incorporating BC for the implementation (Kering 2024).

This highlights the role of consumer behavior in promoting environmental responsibility by empowering individuals to make informed choices that support decarbonization (McKinsey 2022a). For instance, carbon labeling enhances visibility into a product's environmental impact, guiding consumers' purchasing decisions towards more sustainable options (Brenton, Edwards-Jones, and Jensen 2009; Alsayegh, Abdul Rahman, and Homayoun 2020).

Therefore, this part of the thesis shifts the focus to the transparency that traceability provides by disclosing the carbon information collected. However, environmental information disclosure can also negatively influence consumer perceptions. They may perceive the disclosed data as incomplete or selectively presented, raising doubts about a company's sustainability commitment and suspect greenwashing (Zhu, Duan, and Sarkis 2024). Additionally, the complexity and multi-sourced nature of carbon data can hinder verification efforts (Gonçalves and Silva 2021). These issues underscore the challenges associated with environmental information disclosure and highlight the need for transparency practices that foster consumer trust rather than uncertainty.

McKinsey (2022) suggests investing in technology that gives customers easy access to emissions information to facilitate informed decision-making.

3.1.2. Consumer Purchasing Behavior

One of the most promising technologies for preventing incomplete disclosure is BC. The technology is increasingly valued for its ability to provide secure, traceable, and verifiable data. As a result, consumers can easily access further information - f.e. by scanning a QR code - including production location and date, composition, and environmental data (McKinsey 2022b). BCCT is emerging to deliver verifiable carbon data at the product level, aiming to address consumer demand for reliable information on environmental impact (Ji, Zhang, and Yang 2017; Sodhi and Tang

2019). This can potentially strengthen consumer purchase intentions by enhancing confidence in the reported information (McKinsey 2021).

On the one hand, transparency about carbon emissions signals accountability in environmental practices, positively shaping consumer perceptions and increasing their likelihood of purchasing (Borghei 2021). However, Hornibrook, May, and Fearne (2015) highlight that carbon labels alone do not significantly shift consumer demand toward lower-carbon products, which potentially could be reasoned by the missing verification and, therefore, trust.

On the other hand, studies in the food industry show SC traceability through BC enhances purchase intentions by meeting consumer demands for verifiable information, but most of this research focuses on food safety rather than environmental claims (Duong et al. 2024; Kumar, Upreti, and Mohan 2022; Wang et al. 2021; Liu, Wang, et al. 2023; Singh and Sharma 2023). Additionally, studies demonstrate that verified ecolabels can significantly influence consumer behavior in retail. For instance, Navas et al. (2021) show that BC-based ecolabels positively impact purchase intentions by providing detailed environmental information, appealing particularly to younger, eco-conscious consumers. Particularly regarding carbon information, Zhu, Duan, and Sarkis (2024) show that BC made carbon data accessible, and consumers can view retailers more favorably and show a higher willingness to pay for both products and shipping.

Further research is needed to determine if implementing BCCT can drive purchasing behavior in the broader retail context. Based on these insights, the following hypothesis is proposed:

Hypothesis 1 (H_1): *BCCT positively impacts consumers' purchasing behavior towards European retailers.*

3.1.3. Perceived Transparency

Perceived Transparency is the perceived quality of intentionally shared information and is defined by the clarity, openness, and precision of an organization's disclosure (Schnackenberg and Tomlinson 2016). It is crucial in shaping consumer purchasing behavior, especially regarding environmental claims. Product ecolabels strengthen consumers' transparency perception, increasing purchasing rates (Thøgersen, Haugaard, and Olesen 2010). Research indicates that labels, which communicate environmental attributes, are linked to stronger consumer preference, higher purchasing rates, and greater product appreciation (Guyader, Ottosson, and Witell 2017). Liu, Ma, et al. (2023) find that especially BC-enabled traceability enhanced consumer perceptions of transparency in agricultural settings by confirming product origin data, outperforming traditional labeling in terms of perceived transparency. Similarly, Duong et al. (2024) show that BC-enabled traceability positively influenced perceived transparency in the organic food sector in Vietnam, which directly affected purchasing intentions. This can be applied to European consumers due to similar demands (Le and Kieu 2019). Likewise, BC-enabled traceability can improve perceived transparency in the meat industry, positively impacting consumer purchasing intentions (Sander, Semeijn, and Mahr 2018). Consumers in sectors prone to quality concerns particularly value the increased transparency, for instance, food, which belongs to the retail industry (Wang et al. 2021). These findings lead to the assumption that the perceived transparency benefits of BC in verifying origin and production information also apply to carbon data in the retail context. However, this specific application still needs to be explored. By enabling clear disclosure, visibility, clarity, and precision, BC could improve perceived transparency, which may, in turn, positively impact consumer purchasing behavior. Therefore, we propose:

Hypothesis 2 (H_2): *Perceived transparency mediates the effect of BCCT on purchasing behavior towards European retailers.*

3.1.4. Consumer Trust

Perceived transparency is a cognitive construct, whereas consumer trust is emotional. They are distinct and have been shown to function independently (Pirson and Malhotra 2011). Consumer trust is the confidence to rely on an organization's information to make decisions under uncertainty, especially for environmental claims such as carbon footprints (Kikuchi-Uehara, Nakatani, and Hirao 2016). This is essential for brand loyalty and long-term engagement (Wu et al. 2021).

Traditional ecolabels are a tool for enhancing consumer trust in environmental claims (Thøgersen, Haugaard, and Olesen 2010). For carbon data specifically, disclosure can reflect accountability and environmental responsibility for consumers (Sodhi and Tang 2019; Borghei 2021). Research by Zhu, Duan, and Sarkis (2024) demonstrates that consumer confidence increases when carbon offset information is perceived as transparent and traceable. More particularly, consumer trust in environmental claims is based on the perceived reliability, credibility, and accuracy of the information (Kikuchi-Uehara, Nakatani, and Hirao 2016). All qualities that are provided by BCCT (Section **Error! Reference source not found.**). Similarly, BC is often termed a "trustless" technology, as its secure, transparent design reduces reliance on third parties and supports consumer confidence in data reliability (Sarkis, Kouhizadeh, and Zhu 2021).

On the one hand, this may result in outperforming other transparency technologies in fostering trust, which is directly linked to purchase intentions (Rapezzi, Pizzi, and Marzocchi 2024). Cao, Johnson, and Tulloch (2023) found that BC can effectively counter greenwashing by providing a reliable record of sustainability claims for retail consumers. F.e., enhanced trust through BC technology can be seen across safety in food retail like olive oil, coffee, and traceable meat,

positively affecting purchase intentions (Kumar, Upreti, and Mohan 2022; Wang et al. 2021; Dionysis, Chesney, and McAuley 2022). In addition, BC adoption has been shown to enhance corporate image through improved trust in processes like recycling (Ma, Ma, and Hu 2024). On the other hand, perceptions do not always align with BC's potential for trust enhancement. A limited understanding of BC's technical nature can cause skepticism, and superficial sustainability claims may be perceived as greenwashing (Ferreira Da Silva and Moro 2021; Liu, Wang, et al. 2023). However, more research on BCCT in retail is needed to understand its value to consumers, as building trust is critical to influencing consumer decisions (Sarkis, Kouhizadeh, and Zhu 2021). Based on the reviewed literature, the following hypothesis is proposed:

Hypothesis 3 (H_3): *Consumer trust mediates the effect of BCCT on purchasing behavior towards European retailers.*

3.2. Empirical Study

This study uses the Stimulus-Organism-Response (SOR) framework to test hypotheses through a quantitative approach, ensuring an empirical foundation for addressing RQ_2. The SOR model is a major framework in environmental psychology, which illustrates how contextual factors (stimuli) influence individuals' internal processes (organism, e.g., emotions, perceptions) and subsequent actions (response, e.g., approach or avoidance behaviors) (Mehrabian and Russell 1974). This study employs this model to explore how BCCT (stimulus) affects consumers' perceptions of transparency and trust (organism) and their behavioral responses regarding purchasing behavior. As conducting a field study to observe actual behavior is not feasible, this study relies on the concept of purchase intention, which strongly predicts consumers' purchasing behavior (Ajzen 1991). A Structural Equation Model is used as it tests relationships between observed and latent variables within a theoretical framework (Figure 3).

3.2.1. Data Collection and Measurement

Data is gathered via an online survey hosted on Qualtrics and distributed through social media over two weeks in November 2023. Of the 130 participants, 17 are excluded due to failing attention-check questions, incomplete responses, non-EU residency, or age-related outliers. The final sample is analyzed using between-subjects to isolate the effect of BCCT. Participants are randomly assigned to one of two experimental groups adapted from Rapezzi, Pizzi, and Marzocchi (2024). The first group serves as a control group and views a product label displaying a numeric carbon footprint as the stimulus (Non-BCCT). The second group sees the same label, enhanced with information about BCCT and a QR code providing the carbon footprint for each step of the SC (BCCT) (Figure 4, Figure 5). To mitigate bias, participants are exposed to only one of the stimuli and subsequently answered questions.

3.2.2. Method and Assumptions

First, all data is analyzed using the IBM SPSS Statistics and R statistical software. The latent variables are measured on a 5-point Likert scale and validated using confirmatory factor analysis in SPSS to see whether the items accurately represent the constructs, with all factor loadings exceeding the 0.5 threshold (Kline 2014). Afterward, reliability is confirmed via Cronbach's Alpha, with all items surpassing the 0.7 benchmark (Cronbach 2004) (Table 6). Given the alignment with prior studies, these results are considered transferable. Pearson correlations between independent variables are calculated to rule out highly correlated independent variables. Despite a moderate correlation between trust and transparency, the Variance Inflation Factor (VIF) confirms that both variables can be included in the analysis without concerns of multicollinearity (Table 7). Despite a moderate correlation between trust and transparency, the Variance Inflation Factor (VIF) confirms that both variables can be included in the analysis ruling out multicollinearity (Table 7).

Hypotheses and the control variables are tested using multiple regression and mediation analysis in R. Maximum likelihood estimation and 5,000 bootstrap samples are employed to evaluate indirect effects, ensuring robust estimates of the mediation pathways. Regression analysis assumes linearity between independent and dependent variables, which is confirmed by scatter plots (Figure 6). In addition, the residuals are normally distributed and homoscedastic, indicating consistent variance across predictor levels (Figure 7, Figure 8). These findings support the reliability of the model. Since self-reported data is the only viable source, participant responses are assumed to be accurate.

3.3. Results

This study examines the impact of BCCT on consumer purchase intentions, focusing on transparency and trust as potential mediators.

3.3.1. Preliminary Analysis

The survey includes 113 valid respondents, with 64 assigned to the control group (non-BCCT) (0) and 49 to the BCCT group (1). The gender distribution shows that 57% identify as male and 43% as female, and most participants are German (82%). In the EU, 33% of individuals have completed tertiary education (European Commission 2024a). This figure is more than double among survey participants, at 72.6%[1], reflecting the overrepresentation of highly educated individuals. The survey sample predominantly comprises younger individuals, with 84%[2] aged between 18 and 34 years, compared to a much smaller proportion of this age group in the EU population, where older age groups dominate (United Nations 2024). The mean scores for perceived transparency, consumer trust, and purchase intention are slightly higher in the non-BCCT group (M = 3.33, 3.22,

[1] Secondary education: 22.1%, Bachelor's: 42.5%, Master's degree: 25.7%, PhD or higher: 4.4%, Other: 5.31%.
[2] 18–24 years: 56%, 25–34 years: 28%, 35–44 years: 3%, 45–54 years: 5%, 55 years and above: 6%.

3.54) compared to the BCCT group (M = 3.30, 3.12, 3.30) but not significantly (Table 8). Additional analysis can be seen in Table 9.

3.3.2. Regression Analysis

The *direct effect* of BCCT on future purchase intentions is negative (β = -0.125, p = 0.126). However, it is not significant, indicating that BCCT alone does not directly increase purchase intentions, indicating that H_1 is not supported. For the *mediation pathways*, perceived transparency and trust are tested as mediators between BCCT and purchase intentions. The analysis reveals that BCCT does not significantly influence perceived transparency or trust, and neither variable mediates its effect on purchase intentions. Consequently, H_2 and H_3, are also not supported. However, both *mediators independently* have significant positive effects on purchase intentions. Higher levels of trust (β = 0.336, $p < 0.001$) and perceived transparency (β = 0.255, $p = 0.008$) are associated with greater purchasing intentions. The *total effect* of BCCT on purchase intentions is not significant. A multiple regression analysis with transparency, trust, and BCCT as predictors further confirm the significance of the mediators for purchase intention, though displaying BCCT remained non-significant. This model explains 28.7% of the variance in purchase intentions and is significant (F = 14.635, $p < 0.001$), underscoring the importance of trust and transparency as predictors. Including *control variables* (age, education, and gender) reveals that gender significantly influences purchase intentions (β = 0.183, p = 0.030), while other results remain unchanged. The expanded model explains 32.9 % of the variance in purchase intentions (R^2 = 0.329) and is also significant (F = 8.659, $p < 0.001$). See Table 10 for further details.

Table 1. *Coefficients (Purchasing Intention Regression)*

	Purchase Intention	**Purchase Intention** incl. Control Variables
Transparency	0.255**	0.262**
Trust	0.336***	0.307**
BCCT Group	-0.125 (n.s.)	-0.159 (n.s.)
Gender		0.183*
Education		-0.007 (n.s.)
Age		-0.113 (n.s.)
R^2	0.287	0.329
Adjusted R^2	0.268	0.291
F	14.635***	8.659***

*Notes: * p<0.05, ** p<0.01, *** p<0.001, standardized path coefficients*

3.4. Discussion

This section provides a systematic interpretation and explanation of the study's findings, assuming that purchase intention equates to purchasing behavior.

3.4.1. Demographic Explanation

Female participants show higher purchasing behavior than male participants. This is consistent with McKinsey (2021), stating that women value sustainably marketed products more than men. Education and age do not show significant effects, indicating that these factors are relatively consistent across respondents. The overrepresentation of younger and highly educated participants in the study may also explain the limited role of these demographics.

3.4.2. No Effect of BCCT Display on all Variables

BC has no significant effect on perceived transparency, consumer trust, or purchasing behavior, suggesting that including the technology behind the carbon footprint does not resonate with consumers. This finding underscores the potential challenges of implementing BCCT in consumer-facing applications without additional supportive measures.

Complexity of BC Technology. A key barrier to the impact of BCCT is the inherent complexity of the technology. Often perceived as a "black box," consumers may trust the outcomes (e.g., emission data) without understanding the underlying processes (Liu, Wang, et al. 2023). These findings are consistent with Shew et al. (2022) findings for the meat industry that retailers should focus more on product data than the technology that enables it. This disconnect weakens the potential of BCCT.

Trust Paradox. While BC aims to reduce reliance on traditional trust mechanisms, this shift can paradoxically erode trust. Consumers often struggle to trust unfamiliar systems that lack intermediaries, fostering skepticism (Dupuis et al. 2021). Additionally, consumers tend to value honesty-related actions over data reliability when making purchasing decisions (Khamitov et al. 2024). The volume and complexity of BCCT information can overwhelm consumers, reducing their perceived value in promoting transparency and trust, as they do not understand the value of BC in verifying transparency (Rapezzi, Pizzi, and Marzocchi 2024). Ospital et al. (2023) further argue that traceability information does not integrate without narratives that build trust by providing precise and relatable evidence.

Privacy and Perceptions of BC. Privacy concerns further hinder trust, as BCCT can be seen as intrusive (Ferreira Da Silva and Moro 2021). When scanning a QR code, retailers may collect consumer information, which could make some consumers hesitant or unwilling to scan it. Moreover, one interviewee notes that consumers often avoid scanning QR codes even for raffles, so they would unlikely be motivated to scan them for carbon data (I5). Negative media coverage, especially about cryptocurrency scams, exacerbates distrust in BC applications (Treiblmaier and Gorbunov 2022). Some companies actively “try not to use the word BC because it's super scary for people. They associate it with Bitcoin.” (I4).

Consumer Attention Limitations. Consumers have limited cognitive capacity to process information during decision-making, focusing on only 2% of their visual field (Balcombe et al.

2014). This selective filtering explains why BC features failed to function as significant stimuli in line with the SOR model. Consumers prioritize simpler and more accessible information over complex data, such as those provided by BCCT.

Greenwashing and Skepticism. Greenwashing perceptions could undermine the effectiveness of BCCT for consumers, even though it objectively enhances the reliability of the provided information. However, consumers may not yet fully understand or appreciate this added reliability. Exaggerated or unclear sustainability claims can also lead to skepticism, even when the efforts are genuine (Liu, Li, et al. 2023). Research suggests that sustainability claims only drive positive purchasing behavior when consumers fully understand the transparency and trust the information provided at the point of purchase (Hoogland, de Boer, and Boersema 2007).

Product Type Sensitivity. The lack of product specification in the study likely contributed to the non-significance of findings. BC-enabled traceability has been shown to have a stronger effect on products requiring higher consumer trust, such as food or health-related items (Wang et al. 2021). Generic retail products may not evoke the same level of consumer engagement.

Sustainability Fatigue, caused by frequent exposure to complex or conflicting sustainability claims, reduces consumer engagement (Liu et al. 2023). The detailed data provided by BCCT may be dismissed as overwhelming or generic rather than serving as a motivating factor. Effective traceability must be relevant and easily digestible, which the BCCT implementation in the study may have failed to achieve.

Knowledge Gaps and Consumer Reluctance. Consumers' limited understanding of carbon data, such as carbon footprints, diminishes the perceived value of BCCT. While environmental concerns are growing, the lack of familiarity and comparability with sustainability metrics (especially carbon footprints) prevents consumers from fully appreciating BCCT's significance in enhancing the reliability of these claims (Camilleri 2020). Moreover, consumer reluctance to pay a premium for

sustainability-focused products likely contributed to BC's limited impact. Despite expressing a preference for sustainable goods, actual purchasing behavior often falls short (McKinsey 2022b).

3.4.3. Effect of Mediators on Purchasing Behavior

Role of Transparency in Enhancing Purchasing Behavior. Perceived transparency positively impacts purchasing behavior by fostering consumer confidence and loyalty (Duong et al. 2024). The study corroborates this finding, demonstrating that perceived transparency alone can drive purchasing behavior. By addressing consumers' cognitive needs, transparency provides the necessary clarity and detailed information for informed decision-making. This aligns with prior research emphasizing transparency's role in enhancing consumer perceptions and engagement. F.e., Buell and Kalkanci (2019) found that internal environmental transparency enhances the purchase probability by more than 45%, which fits our result of a moderate positive relationship.

Role of Trust in Enhancing Purchasing Behavior. Trust also seems to play a pivotal role in driving consumer behavior in the European retail sector. The study highlights that trust fosters purchasing behavior. Attitudes, such as brand loyalty, foster trust and could be the reason for the enhanced likelihood of future purchases (Khamitov et al. 2024). This emphasizes the role of trust in building long-term customer relationships and the importance of mitigating perceived risk, which is in line with other studies (Harrison McKnight, Choudhury, and Kacmar 2002). If consumers understand the risk reduction through BCCT, they may appreciate its value.

Relative Importance of Trust Over Transparency. The findings suggest trust has a stronger impact on purchasing behavior than transparency. Trust addresses emotional needs by reducing uncertainty and perceived risks, reassuring consumers during decision-making. Trust is about confidence in the party providing the information, in this case, the retailer. So, we see that this is more important to their purchasing behavior than the openness and clarity of the information itself.

This prioritization of emotional over cognitive factors suggests that consumers rely more on feelings of reliability and security than factual clarity when choosing to purchase.

Interplay Between Transparency and Trust. The high correlation between transparency and trust observed in the study indicates that these constructs are closely intertwined in consumers' perceptions. Transparent retailers are often viewed as more trustworthy, supporting previous research (Rapezzi, Pizzi, and Marzocchi 2024). Despite this correlation, transparency and trust independently impact purchasing behavior. While transparency satisfies cognitive needs, trust fulfills emotional needs, creating a complementary relationship between the two.

3.5. Conclusion

While BCCT has significant potential to enhance consumer transparency and foster trust in retailers, evidence of its ability to drive changes in consumer purchasing behavior remains limited. Nevertheless, consumer trust and perceived transparency are key factors influencing purchasing decisions. This suggests that effective consumer communication and education are essential to bridge the gap between consumers' understanding of BCCT and its actual contributions to transparency and trust.

Carrefour's commitment to "satisfy, inform, and engage our customers" highlights the importance of engaging consumers as an integral part of BCCT implementation. European retailers must go beyond merely adopting BCCT - they must also prioritize meaningful consumer education, communication, and engagement for a positive impact.

3.6. Limitations and Future Research

While this study highlights the effects of BCCT on consumer perceptions and purchasing behavior, several limitations should be acknowledged.

First, reliance on self-report data may be subject to social desirability bias. This is also supported by Hamari, Sjöklint, and Ukkonen (2016), who found that consumers exaggerate their interest in sustainability. However, this issue is partially addressed through anonymous data.

Moreover, the study focuses on purchase intention, which may not necessarily translate into actual behavior due to the well-documented intention-behavior gap (Ajzen 1991). The survey may also oversimplify real-world purchasing scenarios, where factors like design, position or convenience also play a significant role. Similarly, the impact on prices is not identified in the study. Nevertheless, research suggests that retailers have to assess the trade-off between price increases and the value of BCCT, especially in trust-lacking sectors (Biswas et al. 2023). Future studies should incorporate experimental field designs to capture the complexity of consumer decision-making better. Addressing these gaps will enable further research to provide a deeper understanding of BCCT's impact. Specifically, research should explore whether consumers actively engage with QR codes in real-world settings and analyze behavioral data to validate these findings and close the intention-behavior gap.

Differences in stimulus may have impacted the quantity, interactivity, or vividness of the information between the two groups rather than solely the BCCT feature. However, prior research by Rapezzi, Pizzi, and Marzocchi (2024) found that interactivity through QR codes and vivid information presentation does not affect consumer perceptions, which is likely the case in this study, given the similar context. However, incorporating additional experimental conditions into the empirical study, such as varying levels of information richness (e.g., detailed vs. minimal carbon data), could provide richer insights into the nuanced ways BCCT impacts consumer perceptions across diverse contexts.

Moreover, the specific retail product is not determined, although BCCT’s impact may vary depending on the product category. Future research should examine the differences across product

categories to help retailers determine whether implementing BCCT in specific categories can enhance purchasing behavior.

While purchasing behavior is the primary outcome, other key performance indicators, such as brand image or customer loyalty, may be impacted by BCCT and need further investigation.

In addition, trust and transparency are considered as separate mediators, whereas some studies claim that transparency is an enabler of trust. However, multicollinearity is ruled out. This relationship should be further explored in the future.

Moreover, the study's findings may not generalize across regions with varying levels of institutional pressure for climate action. For instance, carbon disclosure may be perceived as an expectation in sustainability-focused markets, limiting its reputational impact (Borghei, 2021). The greatest proportion of our study is from Germany, Europe's most important retail market in terms of turnover (Statista Research Department 2024b). Results are still heavily weighted towards the German market. Moreover, the sample primarily consisted of young and educated participants, potentially creating a bias that does not reflect broader demographics. Future studies should expand geographic diversity to include regions with differing levels of institutional and consumer focus on sustainability. This would help assess the variability in BCCT's perceived value and impact across markets.

4. Implications

Based on our findings, this section presents practical implications for European retailers. We synthesize these insights into five dimensions: Stakeholder education and training (Section 4.1), stakeholder communication (Section 4.2), stakeholder collaboration (Section 4.3), operational deployment (Section 4.4), and policy implications (Section **Error! Reference source not found.**). See Figure 11 for a visualized overview.

4.1. Stakeholder Education and Training

Consumer Education. Companies must educate consumers to bridge the gap between technological complexity and consumer trust. The study results in Section 3 show that BC usage and the display of carbon data via the QR code do not currently provide the clarity consumers need. Therefore, educational initiatives are vital to improving consumer understanding of BC's role in enhancing data authenticity. As one industry expert states, "There's a need for more education on this topic, which (should be) addressed through social media, advertisements, and websites" (I9). Without adequate understanding, consumers undervalue BC's role, limiting its ability to influence purchasing behavior (Duong et al. 2024). Educational efforts must focus on illustrating how BC technologies enhance traceability and reliability in ways that are relevant to consumers. Moreover, while BC enhances transparency, it also collects data that may raise concerns about personal information security (Ferreira Da Silva and Moro 2021). Therefore, implementing robust privacy protection is critical as privacy concerns remain a significant barrier to trust in BC technologies, hindering consumer confidence. Educational initiatives must demonstrate the balance between improved transparency and data privacy.

4.2. Stakeholder Communication

Segmenting, Targeting, Positioning. Firstly, the results of the consumer study (Section 3) show that BCCT's effectiveness is not self-evident and depends on context-specific application and communication. As one industry expert explains, the effect "depends on how you are positioned as a company, what your focus market is" (I7), underscoring the importance of aligning BCCT with market segments, consumer needs, and niches. Market segmentation is critical, as not all consumers prioritize detailed SC information. For instance, different generations prefer distinct sustainability communication approaches: Millennials with higher incomes and education gravitate towards clear

carbon-related information, while Generation X relies more on traditional ecolabels (Balcombe et al. 2014; NYU Stern 2023). Retailers should customize marketing strategies accordingly - using tech-forward carbon labeling for younger consumers and familiar sustainability symbols for older demographics who may require educational support. Notably, BCCT also provides reliable environmental data that can serve as a foundation for enhancing the credibility of traditional labels preferred by older consumers. Furthermore, it is essential to use channels that resonate with the target demographic. F.e., it is particularly effective to communicate through social media for younger consumers, as 74% rely on these platforms for decision-making (Forbes 2017).

Positioning BCCT as a trust-building tool is also context-dependent. Research shows that displaying BC-enabled carbon information on a product is particularly effective for companies facing consumer trust deficits, as it can enhance credibility and transparency (Ma, Ma, and Hu 2024). However, for companies with high levels of existing trust, BCCT may add unnecessary complexity and risk alienating their audience. Thus, retailers must carefully assess their market positioning and focus audience to determine whether BCCT implementation will enhance or detract from their value proposition. In addition, retailers can assess the value of BCCT within their product portfolio and implement the technology for specific products where consumers value traceability.

Consumer Sustainability Communication. Secondly, consumers generally favor simple, relatable information over complex data. One industry expert notes that consumers "tend to focus more on (easy) labels, which are concepts everyone can understand" (I9). Overly technical information, such as BC-enabled carbon footprint labels, can overwhelm consumers and foster distrust in the technology (Rapezzi, Pizzi, and Marzocchi 2024; Treiblmaier and Gorbunov 2022) (I4). Instead of showcasing which technology is used to determine the displayed carbon footprint - as done in the

survey - simple sustainability labels should be used. This approach could help mitigate the risk of negative perceptions associated with BC (Section 3.4.2).

Sustainability labels are an effective tool for boosting consumer confidence by simplifying the assessment of sustainability information, complemented by the QR Code and numeric footprint on the packaging. However, they must be clear, relevant, and seamlessly integrated into decision-making processes (Iraldo, Griesshammer, and Kahlenborn 2020). For maximum effectiveness, carbon footprint labels should combine categorical, color-coded, and numeric formats, as proposed by Lemken, Zühlsdorf, and Spiller (2021). We recommend stoplight-style labels enabling quick, intuitive comparison (Figure 10). This could help retailers enhance BCCT engagement - and encourage low-carbon choices (Andrews et al. 2014; Holenweger, Stöckli, and Brügger 2023). The QR code should then direct interested users to a clean, easy-to-navigate interface that presents the more detailed carbon data in an accessible, intuitive, and engaging way. According to the Technology Acceptance Model, technology adoption is largely driven by ease of use (Davis, Bagozzi, and Warshaw 1989). A seamless experience can bridge the gap between quick, in-store decision-making and a deeper understanding of sustainability information, ultimately enhancing interaction and purchases.

In addition, consumer trust and perceived transparency are often more closely tied to brand image and effective communication than to specific technological solutions like BC (Foxall, Oliveira-Castro, and Porto 2021). Therefore, storytelling could be a transformative tool in influencing consumer behavior, as narratives help consumers connect with sustainability claims. Stories illustrating positive impacts can make the carbon data more relatable and emotionally engaging. One industry expert stresses consumers need “other evidence to show why the data is trustworthy - maybe a success story” (I5). These should include retailers’ commitment to accurately and transparently inform consumers and back this up with stories that personalize the sustainability

journey and emotionalize the topic (Navas et al. 2021; Ospital et al. 2023). Similarly, storytelling could enhance employee attraction by strengthening the company's reputation.

In the long term, in contrast to our results from Section 3.3.2, BCCT could then serve as a stimulus for ensuring transparency and fostering complete consumer trust, provided it is supported by effective communication, education, and increased consumer awareness, as these elements align with the technology's capabilities.

Consumer Incentives and Engagement. Thirdly, reward systems and gamification can further enhance the effectiveness of BCCT on purchasing behavior by motivating consumers to make sustainable choices and improving their in-store experience. For instance, QR codes could display cumulative carbon savings, providing a sense of achievement and encouraging more profound engagement. Consumers increasingly seek interactive and immersive retail experiences and respond positively to innovative tools, such as BCCT (Savastano, Barnabei, and Ricotta 2016). Additionally, fostering community building through apps or platforms can create a collective sense of purpose among consumers. Such tools can promote shared sustainability goals, encouraging deeper engagement with the retailer and changing purchasing behaviors (Huang, Su, and Peng 2022). A notable example is Ben & Jerry's pilot program in London, which partnered with Poseidon to offer a platform allowing consumers to offset the carbon footprint of their purchases, combining BCCT with tangible incentives (Smith 2018).

4.3. Stakeholder Collaboration

Industry-Wide Standardization. Moreover, according to industry experts, an industry-wide solution is essential for large-scale implementation of BCCT in retail (I1, I5, I7, I8, I9). One industry expert claims that "standardized data allows all stakeholders to work from a common platform, simplifying communication, decision-making, and goal alignment across the supply chain" (I2).

To ensure this consistency and simplify emissions reporting, we recommend that retailers working with organizations such as GS1 (I7) establish common metrics and standards for carbon traceability Standardization will reduce complexity for suppliers and increase transparency for consumers (Ehrler et al. 2016). A strong example of this collaborative approach is the Aura Blockchain Consortium, where luxury industry leaders Prada, Cartier, and Louis Vuitton partnered as competitors to develop a BC-based solution for shared challenges like transparency and traceability (Aura Consortium 2022). By opening the platform to all luxury brands, they fostered collaboration and established a unified standard, demonstrating how industry-wide solutions can drive consistency and scale across a sector. These efforts would also be in line with broader EU objectives for harmonized sustainability reporting under initiatives such as the CSRD.

4.4. Operational Deployment

Piloting. Above all, piloting is essential before scaling up to ensure a smooth operational deployment of BCCT. Hoek (2019) confirms this by highlighting the importance of targeted BC pilots in SCs to evaluate feasibility, costs, and benefits, drawing lessons from early adopters in logistics, consumer products, and retail industries. As already mentioned, Walmart piloted BCCT with mangoes in the U.S. and pork in China, collaborating with IBM for technology implementation, also demonstrating the value of third-party providers (Tan et al. 2018; Sharma and Kumar 2021). Furthermore, we recommend that BCCT be trialed within regional SCs to reduce complexity and minimize the need for extensive process changes. Focusing on a specific product category could further simplify pilots while generating insights applicable to other segments. Lastly, stakeholder buy-in throughout this process is crucial, as mentioned above.

5. Conclusion

This thesis analyzes how BCCT impacts SC performance, purchasing behavior, employee attraction and retention, and stock price performance, ultimately contributing to overall firm performance in the European retail sector.

The findings reveal that BCCT enhances the four considered SC metrics: efficiency, transparency, trust, and sustainability. However, these effects rely on the presence of specific enablers identified in expert interviews, namely Supplier Education, Industry-wide Standardization, Integration with Complementary Technologies, and Long-term Supplier Relationships. Assuming these enablers are in place, the enhanced SC metrics positively impac firm performance, with SC performance acting as a mediator.

Regarding purchasing behavior, BCCT does not currently appear to affect this variable, either directly or mediated by perceived transparency or consumer trust. Nevertheless, perceived transparency and trust independently drive purchase intentions, suggesting that consumer education and effective communication on the actual benefits of BCCT could narrow the gap between actual and perceived effects. This could eventually result in a positive impact on purchase intentions, which would, in turn, enhance firm performance.

The findings also indicate that BCCT impacts employee attraction and retention by enhancing the firm’s environmental responsibility. Since attraction and retention contribute to firm performance, BCCT indirectly enhances firm performance through its impact on environmental responsibility. This effect is particularly strong among younger generations and individuals with strong ecological values.

Furthermore, BCCT can positively impact a company's EPS, which, in turn, shows a statistically significant positive relationship with stock prices over the past 15 years. By improving environmental valuation, BCCT may indirectly boost overall company performance.

In response to the umbrella RQ, this thesis concludes that BCCT can positively impact the performance of European retailers. This impact is observed across four key areas: SC performance, purchasing behavior, employee attraction and retention, and stock price performance. However, the impact level depends on Stakeholder Education and Training, Stakeholder Communication, Stakeholder Collaboration, and Operational Deployment, as outlined in the preceding section. Additionally, we suggest two policy implications, recognizing that incentives from the public sector also play a crucial role in the success of BCCT.

This thesis contributes not only to a more comprehensive understanding of effective BCCT in the European retail sector but also supports alignment with EU mandates to ultimately become the world's first climate-neutral continent by 2050.

6. Limitations and Future Research

This section discusses the limitations of this thesis, addressing constraints in scope, methodology, and analysis that impact the comprehensiveness and generalizability of the findings.

Use of Mediators. The analysis relies on mediated relationships to evaluate the impact of BCCT on stock price performance, consumer purchase intention, and talent attraction and retention. While this approach is widely accepted in academic research and supported by theoretical and empirical evidence, it does not establish direct causal links. Consequently, other unmeasured factors may influence the mediators. Future research could aim to isolate and directly measure these effects to enhance the robustness and conclusiveness of the findings.

Focus on Application of Technology. This thesis examines the application of BCCT in the retail sector; however, it does not delve into the technical development of BC systems, such as algorithms, coding structures, or smart contract design. Future research should address these

technical aspects to uncover potential constraints and enhance the optimization of BCCT implementation.

Heterogeneity of Retailers. The recommendations are generalized to address challenges across the European retail sector but may not fully account for the specific needs of individual retailers. Even touched upon briefly, differences in company size, resource availability, technological infrastructure, and market positioning may affect the feasibility and effectiveness of these recommendations. Future research could focus on creating more tailored strategies that align with diverse organizational capabilities and market conditions.

Lack of Quantification of Performance Impact. Although this thesis evaluates the impact of BCCT across four key metrics, it does not include a quantitative assessment of firm performance. The analysis focuses on qualitative insights and theoretical frameworks, leaving the magnitude of the effects unmeasured, as this would exceed the scope of the thesis. This limitation restricts the ability to compare the benefits of BCCT adoption against its costs or to evaluate its return on investment in measurable terms. Future research should incorporate quantitative methods, such as cost-benefit analysis or performance metrics modeling, to provide a clearer picture of the tangible impacts of BCCT on firm performance.

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List of abbreviations

BC	Blockchain
BCCT	Blockchain-enabled Carbon Traceability
CSRD	Corporate Sustainability Reporting Directive
EGD	European Green Deal
EPS	Environmental Pillar Score
ESG	Environmental, Social, and Governance
GHG	Greenhouse gas
JPI	Job Pursuit Intentions
LCA	Life Cycle Assessment
MRV	Monitoring, Reporting, and Verification
PoS	Proof-of-Stake
PoW	Proof-of-Work
RBV	Resource-based View
RQ	Research Question
SC	Supply Chain
SOR	Stimulus-Organism-Response
VIF	Variance Inflation Factor

Appendix A

Figure 1. *Research Methodology Overview.*

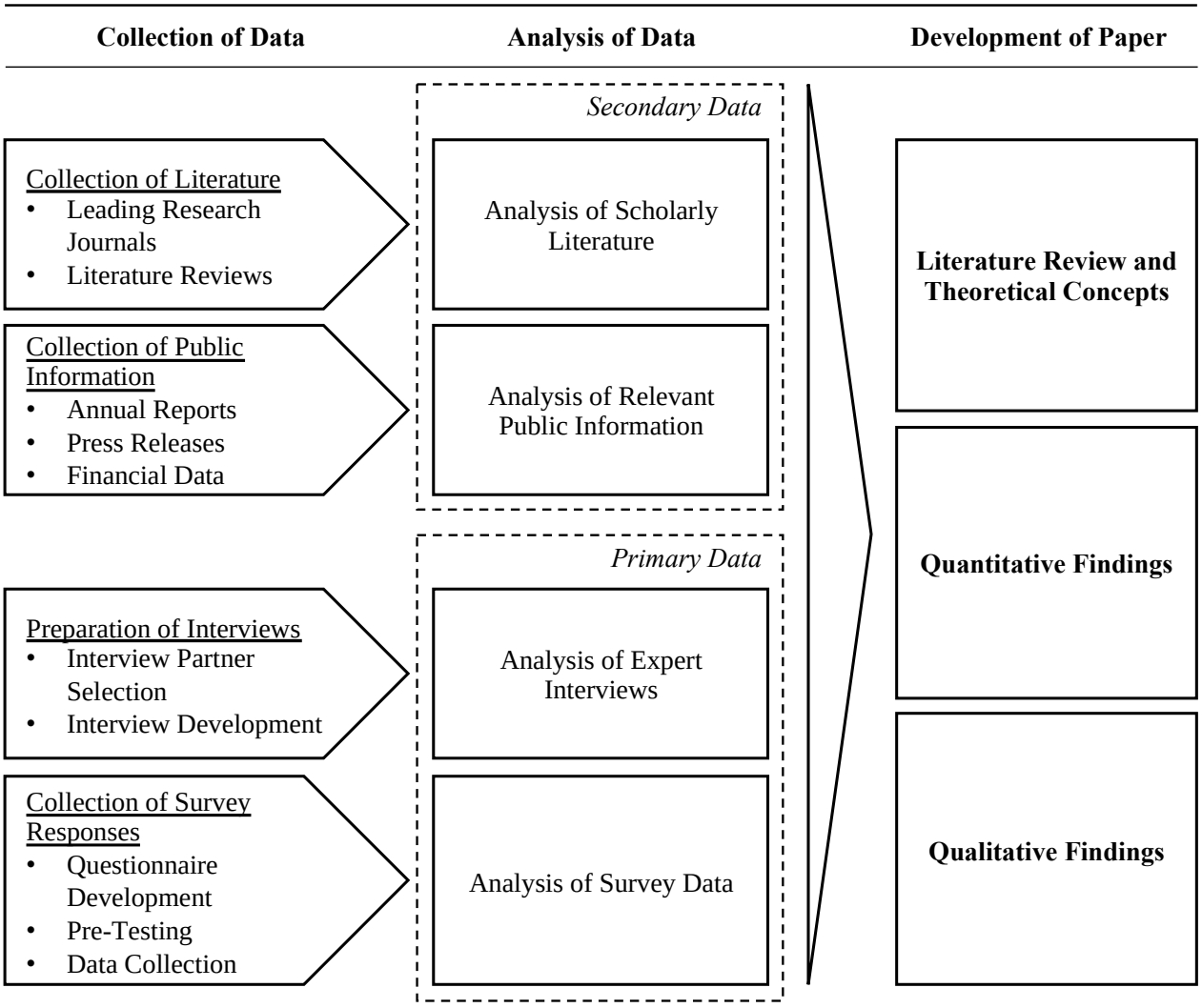

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Figure 2. *Conceptual Model of BCCT Impact on Supply Chain Performance.*

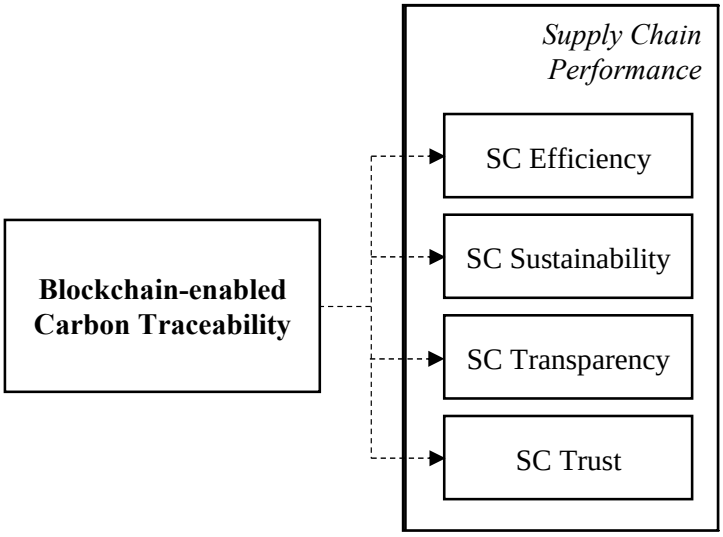

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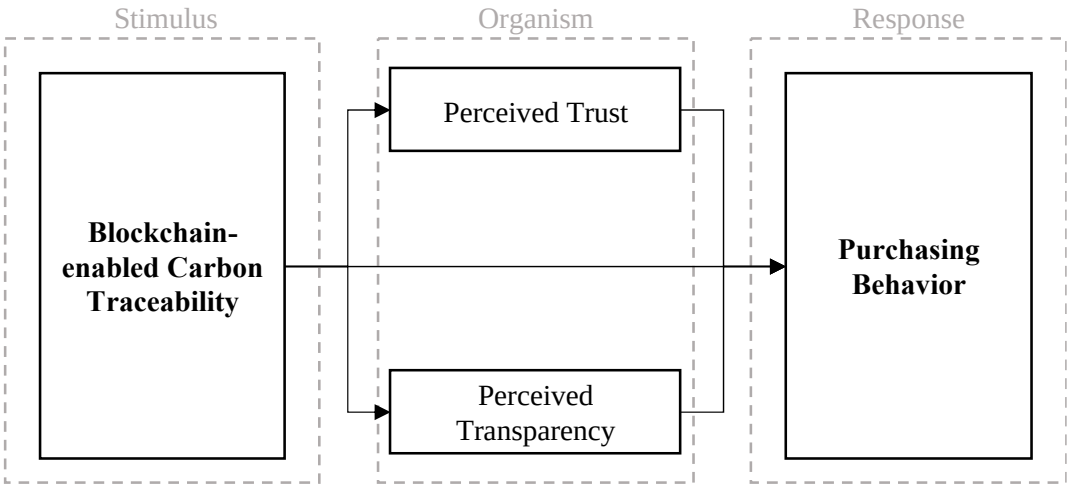
Figure 3. *Conceptual Model of BCCT Impact on Purchasing Behavior.*



Note: Adapted from Theory of Planned Behaviour and SOR Model.

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Figure 4. *Stimulus Shown to the BCCT Group in the Survey.*

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Figure 5. *Stimulus Shown to the Non-BCCT Group (Control Group) in the Survey.*

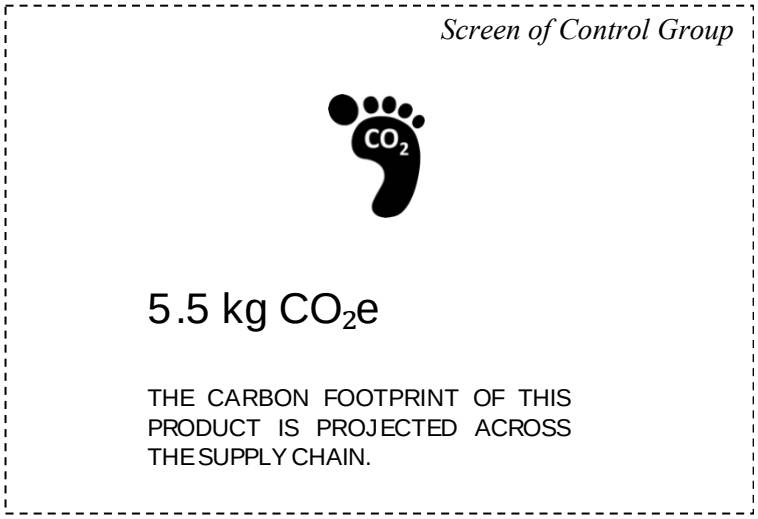

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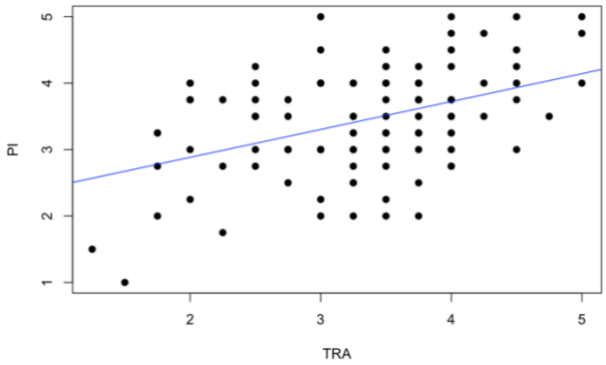
Figure 6. *Linearity Assumption (Example Transparency).*



The *linearity assumption* tests whether there is a linear relationship between the independent variable (Transparency) and the dependent variable (Purchase Intention). The scatterplot shows that the data points align reasonably well around the regression line. This indicates that the relationship between Transparency and Purchase Intention is approximately linear. However, some variability in the scatter of the points, particularly at the lower and upper ends of Transparency, suggests that further inspection for outliers or transformations may be useful. Using the outlier test in R, observation 55 is identified as having the largest studentized residual. However, the

Bonferroni-corrected p-value indicated that this observation is not a statistically significant outlier. Therefore, it is not necessary to exclude any data points from the analysis.

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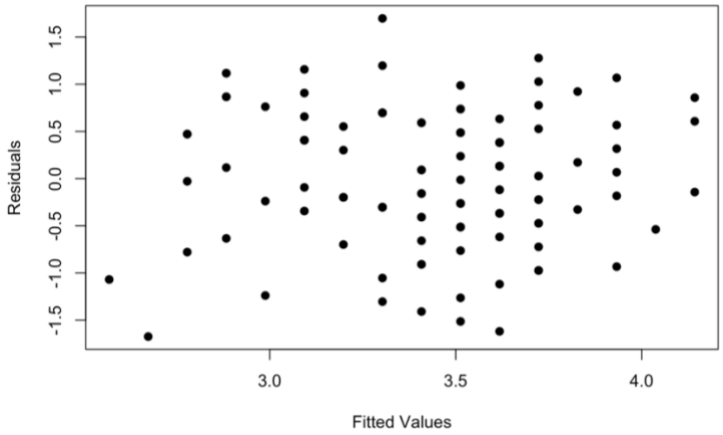
Figure 7. *Homoscedasticity Assumption (Example Transparency)*



Homoscedasticity assumes that the residuals have constant variance across all levels of the fitted values (predicted Purchase Intention values). The residual plot shows residuals that appear randomly scattered around zero without a discernible pattern. This indicates that the variance of the residuals is roughly constant, and the homoscedasticity assumption is likely met. No evidence of heteroscedasticity (e.g., cone shapes or clustering) is observed.

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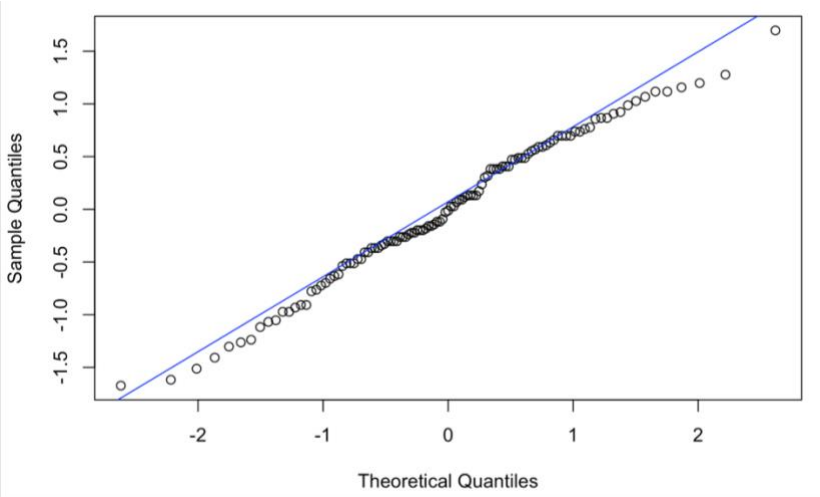
Figure 8. *Normality of Residuals (Example Normal Q-Q Plot for Transparency)*



Normality assumes that the residuals are normally distributed, which is important for valid hypothesis testing and confidence intervals. The Q-Q plot ("Normal Q-Q Plot of Residuals for Transparency") shows that the residuals mostly align along the diagonal reference line, indicating that they are approximately normally distributed. Minor deviations at the tails are visible but are not extreme, suggesting no major violations of the normality assumption.

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Figure 9. *Conceptual Model of BCCT Impact on Stock Price Performance.*

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Figure 10. *Visualisation of Stoplight Implementation.*

Traffic Light Color Variations

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Figure 11. *Visualization of Implications.*

Stakeholder Education and Training

- Supplier Training
- Consumer Education
- Employee Training
- Investor Education

Stakeholder Communication

- Segmenting, Targeting, Positioning
- Consumer Sustainability Communication
- Consumer Incentive Engagement
- Internal Sustainability Communication
- Investor Sustainability Communication

Stakeholder Collaboration

- Supplier Collaboration
- Collaborative Data Sharing
- Third-party Service Provider
- Industry-Wide Standardization
- Legislative Advocacy and Lobbying

Operational Deployment

- Targeted Recruitment
- Stock Options for Employees
- EU Funding Opportunities
- Integration with Complementary Technologies
- Energy-efficient Solutions
- Piloting

Policy Implications

- Consumer Awareness Campaigns
- Governmental Incentives

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Appendix B

Table 2. *Semi-structured Interview Guide.*

Introduction
Thank you for agreeing to participate in this interview. My name is Alexander Ritter, and this interview is part of my master's thesis research at the Nova School of Business and Economics. With increasing sustainability requirements and EU regulations such as the EGD and the Carbon Border Adjustment Mechanism forcing companies to prioritize carbon traceability, I am investigating how blockchain-enabled carbon traceability influences supply chain performance in the retail sector, focusing on metrics such as efficiency, transparency, trust, and sustainability. The interview will take approximately 30-40 minutes. Your responses will be kept confidential, and we can provide a non-disclosure agreement if needed. Is it also okay to record this interview? Any questions before we begin?

Topics/Subtopics	**Questions**
Introductionary Question	1. Could you please introduce yourself, Company X and you role at Company X?
Topic 1: Current Standpoint	1. What is your experience with carbon traceability within retail supply chains? 2. What is your perspective on the current state of blockchain adoption for carbon tracing in the retail sector? 3. Scholars have pointed out the challenges of tracing Scope 3 emissions, data fragmentation, and varying stakeholder demands associated with carbon traceability in retail. How would you describe the role of blockchain in addressing these unique challenges?
Topic 2: Efficiency	1. What are your thoughts on blockchain's potential to improve efficiency in carbon tracing within retail supply chains? 2. In your experience, how does blockchain impact the speed and cost of tracing carbon emissions across multi-tier retail supply chains? 3. Do you believe the efficiency gains from blockchain can outweigh the initial investment and operational costs involved? Why or why not?
Topic 3: Transparancy	1. Transparency is often cited as a key advantage of blockchain. How do you see this feature benefiting carbon traceability in retail supply chains? 2. How do you think blockchain transparency impacts the accuracy and availability of carbon data between partners? 3. Some academics argue that despite its transparency, blockchain may lack incentives for certain regions (e.g. Asia) to share accurate carbon data. Do you see this as a limitation for retail supply chains?
Topic 4: Trust	1. Trust is crucial in sharing and verifying carbon data across multi-tiered supply chains. How do you think blockchain's immutability affects trust in carbon tracing for retail? 2. Smart Contracts are another aspect of blockchain that can strengthen partnerships by automating agreements and reducing opportunistic behavior. What role do Smart Contracts play in maintaining trust and collaboration in carbon tracing within retail supply chains?

	3. Blockchain technology may still allow for data misrepresentation due to a lack of motivation for accurate data entry. Do you think that blockchain alone can sufficiently address trust issues related to carbon data accuracy and reporting? Or are complementary technologies needed?
Topic 5: Sustainability	1. What role do you see blockchain playing in supporting retail companies' sustainability goals, especially concerning carbon neutrality? 2. How well do you think blockchain can support retail companies in meeting regulatory compliance requirements from the EU related to carbon tracing and sustainability? 3. Blockchain's energy consumption is often a concern. Do you believe this affects its viability as a tool for promoting sustainability in carbon tracing?
Final Considerations	1. What are the main barriers to implementing blockchain for carbon traceability in the retail sector? 2. Do you think other technologies should complement blockchain to improve carbon traceability or is blockchain alone sufficient? 3. Are there any specific areas within blockchain-enabled carbon tracing that need more research to understand its impact on retail supply chain performance?

Concluding Remarks
Before we wrap up, is there anything else you'd like to add, or are there any other resources or experts you'd recommend I consult on this topic? Thank you so much for sharing your insights today, I really appreciate you taking the time! If you are interested, I would be happy to share a summary of the findings once the research is complete. Additionally, if I have any follow-up questions or need clarification, would it be okay to reach out? Just a reminder that all of your responses will be kept confidential, and any information you provided will be anonymized in my report. Thank you once again, this has been incredibly helpful for my research. Have a great day!

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Table 3. *List of Industry Experts outreached.*

Name	Organization	Position
Christina Rechtsteiner	Munich Electrification	Sustainability Manager
Jelena Nicolic	Deutscher Handelsverband	Head of CSR
João Joanaz de Melo	Nova Professor	Research sustainability assessment
Sahil Baxi	Carbon Chronicles	Founder
Lukas Stumpf	Höveler Holzmann	Nachhaltigkeit in SCM Beratung
Elhoussaine Hosny Wahyana	Université Rabat	PhD Enhancing Supply Chain Sustainability with Blockchain
Ayrton Dhillon	KPMG London	Capital Program Manager
Niccolò Corsini	Logidot	Founder/CEO @ LOGIDOT | Advisory Board Member | Investor
Pavels Sidlovskis	Arcadis	Arcadis
Jessie Brenner	Textile Genesis	Sustainability Strategist | Material Expert
Merel Krebbers	H&M	Director of Solutions Management: Traceability, Compliance and Packaging
Concepción Galdon PhD.	IE Business School	Vice-Dean Business with Purpose (IE Business School)
Olivia de Seze	Aware	Business Development Representative
Lars Kreuchwig	Coca-Cola	BPT Business Partner - PAC & Sustainability
Sophie Van Kol	Fashionforgood	Innovation Manager
Aljosha Rix	GS1	Junior Manager Supply Chain Management
Solenne Zandronis	Wildling Shoes	Supply Chain Sustainability Specialist - Social Impact & Traceability
Alex van der Heyden	Inditex	Sustainability Specialist at Bershka
Rachelle Graham	IKEA	Traceability Leader
Aya Abdelaziz	GS1	Global Sustainability Programme - Capabilities
Koen Warmerdam	Aware	Co-Founder
Tom Weijtmans	VeChain	Community Ambassador
Natalia Montaña	Loewe	Sustainability Compliance & Traceability Specialist
Axel von der Heyden	Inditex	Sustainability Specialist
Aled Davies	Finboot	Technical Lead

Padma Raj Keshri	Ralph Lauren	Regional Sourcing Manager, Traceability
Paola Braione	Richemont	Responsible Sourcing Specialist
Erin Finley	Walmart	Supply Chain Manager
Sophia Burathoki	Walmart	Associate Director, E2E Supply Chain
Sonia Strate	Walmart	Senior Supply Chain Manager
Sahil Bhosale	Walmart	Director, Omnichannel Supply Chain Strategy and Transformation
Niki Lewis	Bext360	Chief Sustainability Officer
Dean Kingston	Bext360	Founder and COO
Daniel Jones	Bext360	Founder and CEO
Karl Bedwell	CPS	Executive Vice President and Chief Information Officer
Surabhi A.	Starbucks	Group Product Manager, Strategy & Innovation
Sébastien Vincent	Louis Vuitton	Traceability & Blockchain Domain Leader
Claudia Lee	Crystalchain	Chef de projet traçabilité
Andreas Weckwert	Nature Office	CEO
Taouifik Manar	Hermès	Supply Chain Traceability Program - IT Manager
Julia Menge	ICF	Lead Management Consultant - Sustainable Finance and Climate Policy
Valeriia Dicken	German Retailer	National Sustainability
(Hoek 2019)	Project Trick	Any
Leonie von Holtz	German Retailer	Specialist Sustainability - Climate
Markus Pawelski	CAS AG	Solution Owner Supplier & Customer Interaction – Retail
Julia Pötsch & Markus Hau	Nestlé	Europe & Supply Chain Director; International Customers & Digital Supply Sales Sustainability Lead Chain

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Table 4. *List of Industry Experts interviewed.*

Name	Organization	Position	ID
Christina Rechtsteiner	Munich Electrification	Sustainability Manager	I1
Sahil Baxi	Carbon Chronicles	Founder	I2
Jessie Brenner	Textile Genesis	Sustainability Strategist/ Material Expert	I3
Olivia de Seze	Aware	Business Development Representative	I4
Lars Kreuchwig*	Coca-Cola	BPT Business Partner - PAC & Sustainability	I5
Sophie Van Kol	Fashionforgood	Innovation Manager	I6
Aljosha Rix	GS1	Junior Manager Supply Chain Management	I7
Solenne Zandronis	Wildling Shoes	Supply Chain Sustainability Specialist - Social Impact & Traceability	I8
Leonie von Holtz & Valeriia Dicken*	German Retailer	Specialist Sustainability - Climate	I9
Markus Pawelski	CAS AG	Solution Owner Supplier & Customer Interaction – Retail	I10
Julia Pötsch & Markus Hau*	Nestlé	Europe & Supply Chain Director; International Customers & Digital Supply Sales Sustainability Lead Chain	I11

*Note: *Expert opinion does not equal company opinion*

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Table 5. *Overview third-party service providers interviewed.*

	Textile Genesis (I3)	**Aware (I4)**
Website	https://textilegenesis.com/	https://news.wearaware.co/
About	TextileGenesis™ is an innovative platform that aims to revolutionize traceability in the fashion and textile industry.	Aware™ combines physical tracer technology with public blockchain technology to deliver reliable and transparent traceability.Their BC enables full traceability of sustainable materials from the fiber level to the finished product utilizing .
Traceability	TextileGenesis uses a fiber-forward traceability approach, leveraging blockchain principles to ensure transparent and reliable tracing of materials: **Fiber Coins**: Digital tokens created at the origin of the material, tracing materials throughout the supply chain to prevent over-claiming and ensure ESG compliance. Traceability Modules: **Fiber to Retail**: Robust tracing of sustainable materials from origin to finished product. **Supply Chain Discovery**: Product backward self-declaration for conventional and sustainable materials. **Supply Chain Mapping**: Simplified mapping for complex categories such as footwear and leather. **AI Integration**: Calculates waste and loss, ensuring material accountability and accurate tracing. This system provides brands with end-to-end traceability and compliance for all material types.	Unlike traditional traceability solutions that work backwards from the finished product, Aware starts at the source-whether it's organic cotton from the field or recycled materials from the factory. Two-Track Traceability: 1. **Digital Platform**: The platform tokenizes materials (e.g., 1 kg of recycled polyester = 1 token) and traces them through the supply chain using a mass balance system. It connects all stakeholders, from spinners to brands, and links material data to the final product via a digital product passport. This passport records compliance (e.g. environmental, social, chemical) and meets global regulations. 2. **Physical Tracer**: A secure, embedded modified ceramic tracer ("like powdered sugar or glass") is added during spinning or ginning. It can be verified with a hand scanner, ensuring authenticity throughout the supply chain. The tracer is safe, invisible and doesn't change the properties of the material.

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Table 6. *Measurement Scales and Reliability (Purchasing Intention Regression).*

Variable (adapted from)	**Cronbach's Alpha**	**Questions**	**Factor Loading**
Perceived Transparency (Montecchi et al. 2024; Fraser and van der Ven 2022; Sodhi and Tang 2019)	0,759	I believe the retailer is being transparent and open about the product's carbon footprint.	0,547
		I can trace the carbon footprint of the product easily.	0,757
		The carbon emission information provided by the company is reliable.	0,521
		The information provided about carbon emissions is clear and detailed.	0,688
Consumer Trust (Navas et al. 2021; Doney and Cannon 1997)	0,782	I am certain that the information about the carbon footprint provided by the retailer is correct.	0,559
		I trust the retailer to provide accurate information.	0,719
		The retailer is being honest.	0,763
Purchase Intention (Navas et al. 2021; L. Zhou et al. 2018)	0,747	I would consider purchasing the product from this retailer, based on given information.	0,645
		I would rather recommend this product to others than without a label.	0,554
		The information about the carbon footprint is useful for informing my purchasing decisions.	0,663
		I would expect to buy the product with this form of carbon information.	0,583

Notes: All factor loadings are significant on a 0.01 level.
All variables ranging from 1 (Strongly Disagree) to 5 (Strongly agree).

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Table 7. *Pearson Correlations (Purchasing Intention Regression).*

	1	2	3	4
1 Transparency	1			
2 Trust	0.511***	1		
3 Purchase Intention	0.428***	0.474***	1	
4 BCCT Group	-0.017 (n.s.)	-0.066 (n.s.)	-0.152 (n.s.)	1

*Notes: * p<0.05, ** p<0.01, *** p<0.001*

Multicollinearity. The Pearson correlation between Transparency and Trust is 0.511, which indicates a moderate relationship and raised the possibility of multicollinearity. To further investigate, we calculated the VIF for these variables. The values for both Transparency (VIF=1.354) and Trust (VIF=1.360) are well below the commonly accepted threshold of 5, confirming that multicollinearity is not an issue in this model. Therefore, both variables can be included in the analysis without compromising the reliability of the results.

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Table 8. *Manipulation Check Test (Purchasing Intention Regression).*

	Mean	BCCT Mean	Non-BCCT Mean
Perceived Transparency	3,316	3,301	3,328
Trust	3,174	3,116	3,219
Purchase Intention	3,436	3,301	3,539

A two-way MANOVA is conducted to examine the effect of BCCT (BCCT: 1.00 = BC-enabled, 0.00 = Non-BCCT) on perceived transparency and trust. The results indicate no statistically significant main effect of BCCT Group on the combined dependent variables. Descriptive statistics showed that participants in the BCCT condition reported slightly lower perceived transparency (M=3.30, SD=0.77) compared to the non-BCCT condition (M=3.33, SD=0.82). Similarly, perceived trust is marginally lower in the BCCT condition (M=3.12, SD=0.65) compared to the

non-BCCT condition (M=3.22, SD=0.86). Purchase intention is also slightly lower in the BCCT condition (M = 3.30, SD = 0.78) compared to the non-BCCT condition (M = 3.54, SD = 0.81). However, these differences are not statistically significant.

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Table 9. *Levene's Test for SD (Purchasing Intention Regression).*

	SD	BCCT SD	Non-BCCT SD
Perceived Transparency	0,797	0,769	0,824
Trust	0,777	0,651	0,863
Purchase Intention	0,781	0,834	0,728

Results. The BCCT group consistently shows slightly lower standard deviations across all variables, indicating less variability in participants' responses compared to the non-BCCT group. The difference in standard deviations for trust is statistically significant at the 0.05 level. The p-value for Levene's test for Trust is 0.034, which is below the 0.05 threshold. This indicates that the variability in trust differs significantly between the BCCT and Non-BCCT groups. For the other variables (perceived transparency and purchase intention), the differences in variances are not statistically significant.

Discussion. For managers in the retail industry, these results highlight BC technology's potential to stabilize trust levels among consumers, fostering more predictable customer relationships. While trust variability is lower in the BCCT group, it is important to note that the mean trust level remains higher in the Non-BCCT group. This suggests that while BCCT promotes consistency, it may not always lead to higher overall trust. To achieve both higher and more consistent trust, managers should implement necessary enablers such as clear communication, user education, and complementary transparency measures alongside BCCT.

Click to return to Section 3.3.1.

Table 10. *Coefficients (Purchasing Intention Regression).*

Coefficients	Estimate	Standardized	Std. Error	t	p
(Intercept)	1,541	NA	0,400	3,850	<0.001
TRA	0,257	0,262	0,091	2,826	0,006
TRU	0,309	0,307	0,094	3,281	0,001
BCCT Group	-0,250	-0,159	0,128	-1,953	0,053
Age	-0,066	-0,113	0,050	-1,327	0,187
Gender	0,259	0,183	0,118	2,200	0,030
Education	-0,005	-0,007	0,064851	-0,084	0,933

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Table 11. *ESG Calculation and Structure.*

Elements	Weight
ESG Score	100,0%
Environmental Pillar Score	23,0%
Social Pillar Score	49,3%
Governance Pillar Score	27,7%

Elements	Weight
Environmental Pillar Score	23,0%
Resource Use	3,7%
Emission	5,5%
Innovation	13,8%

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Table 12. *EPS Criteria Classification.*

Dimension	Count	Share
Directly affected	70	23,5%
Resource Use	*7*	
Emission	*62*	
Innovation	*1*	
Indirectly affected	89	29,9%
Resource Use	*32*	
Emission	*33*	
Innovation	*24*	
Not affected	139	46,6%
Resource Use	*18*	
Emission	*101*	
Innovation	*20*	
Total	298	100,0%

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Table 13. *Model Summary (Stock Price Performance Regression).*

R	R^2	Adjusted R^2	RMSE	F	p
0,528	0,279	0,248	147,718	9.079	< 0.001

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Table 14. *Descriptive Statistics (Stock Price Performance Regression).*

	E Score	S Score	G Score	Employees	Revenue	ROA	Earnings	Current Ratio
Median	59.895	66.215	51.955	26.884	1.509E+08	5.505E+05	1.261E+07	1.340
Mean	58.678	63.158	50.920	4316.241	3.517E+09	5.215E+07	8.977E+08	2.795
Std. Deviation	24.287	23.110	22.454	29803.562	1.775E+10	3.815E+08	7.173E+09	37.380
Skewness	-0.317	-0.614	-0.138	13.827	10.470	3.752	9.909	55.986
Std. Error of Skewness	0.069	0.068	0.068	0.068	0.030	0.123	0.031	0.030
Kurtosis	-0.745	-0.381	-0.896	255.253	134.308	72.907	182.729	3314.725
Std. Error of Kurtosis	0.137	0.136	0.136	0.136	0.060	0.246	0.061	0.060

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Table 15. *Coefficients (Stock Price Performance Regression).*

	Standard Error	Standardized	t	p
(Intercept)	59,816		-2,932	0,004
E Score	0,738	0.94	2,399	0,017
S Score	0,704	0,117	1,343	0,181
G Score	0,639	-0,226	-3,119	0,002
Employees	0,001	0,041	0,588	0,557
Revenue	<0.001	0,381	2,103	0,037
ROA	<0.001	-0,024	-0,280	0,780
Earnings	<0.001	-0,339	-1,705	0,090
Current Ratio	17,343	0,475	7,126	<0.001

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