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Beans, Blockchain, and Beliefs: How German Consumers Perceive Value in Sustainable Coffee Certifications

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Abstract

Given the increasing relevance of sustainability certification in food supply chains and, at the same time, rising confusion among consumers about the multitude of labels on food products, concerns about the value of sustainability certification occur frequently. This paper aims to investigate consumers' evaluation and purchase intentions, and willingness-to-pay (WtP) for blockchain-enabled sustainability certification in coffee. Utilizing a questionnaire guided by an extended model of Ajzen's theory of planned behavior (TPB), an online survey was conducted with n = 400 German consumers. Data were analyzed using structural equation modeling and cluster analysis. The results revealed perceived behavioral control (PBC) and subjective norms (SN) as the most influential factors on WtP, whereas intention to buy is shaped by PBC and environmental concerns. Notably, trust in blockchain technology did not emerge as a significant direct predictor, suggesting it operates as a background condition rather than a behavioral driver. Three distinct clusters were identified with concise preference, intention, and WtP profiles, highlighting heterogeneous consumer motivations. The study contributes to the literature in three ways: it provides the first consumer-behavioral evidence from the German market; it demonstrates that blockchain-specific trust constructs do not constitute independent behavioral drivers, suggesting that adoption follows generic TPB mechanisms; and it empirically differentiates intention and WtP as distinct psychological outcomes driven by different construct sets.

Keywords: sustainability certification; blockchain; consumers' willingness; coffee; theory of planned behavior

1. Introduction

The harmful effects of intensive farming and power imbalances along value chains become particularly evident when examining the coffee value chain. Sustainability certifications have emerged over the past few decades to set standards and make the sustainability efforts of actors in the value chain transparent, thus reducing power imbalances and environmental degradation [1–3]. Still, sustainability certification in the coffee sector faces significant challenges [4,5]. Certification systems often fail to deliver the long-term developmental benefits they promise, such as meaningful price premiums, improved livelihoods, and increased resilience to external shocks [6,7]. For one, the accessibility of smallholder farmers remains pervasive due to high certification costs and limited technical assistance, and the actual impact remains challenging to determine [8]. Moreover, the market for coffee certified as sustainable is currently facing oversupply, with only a fraction of the harvested coffee produced under certified conditions being sold as such [9].

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Due to these challenges, there is a growing consensus that traditional certification systems have deficits in meeting the demands of modern, transparent, and scalable value chains. Traditional certification systems typically rely on paper-based documentation, centralized record-keeping, and periodic third-party audits, which are susceptible to fraud, lack real-time verifiability, and struggle to provide end-to-end traceability across complex, multi-actor supply chains. These limitations emphasize the urgent need for digitally enabled solutions that can enhance efficiency, traceability, and transparency. Several digital technologies have been proposed to address these traceability deficits. QR codes and RFID (radio frequency identification) tags enable product-level tracking and consumer-facing transparency at low cost but rely on centralized databases that remain vulnerable to manipulation and do not guarantee data immutability [10]. IoT (Internet of Things) sensors allow real-time monitoring of conditions along the supply chain yet similarly depend on centralized data infrastructure. Distributed ledger technologies, and blockchain in particular, go beyond these approaches by combining immutability, decentralization, and transparent access in a single system, making them uniquely suited to address the trust and verifiability challenges inherent in sustainability certification [11–13]. These characteristics significantly reduce the burden of compliance, and can make sustainability claims verifiable in real-time, which increases stakeholder trust [10,13]. These technologies have the potential to fill the gaps in traditional certification systems by providing a decentralized, transparent, and scalable platform for verifying sustainability credentials across the entire coffee value chain [14,15].

The theory of planned behavior (TPB) states that a certain behavior is predicted by behavioral intentions, which are a function of attitudes toward the behavior, subjective norms (SN), and perceived behavioral control (PBC) [16,17]. This study aims to elucidate consumers' willingness-to-pay (WtP) for blockchain-enabled sustainability certification in coffee based on the TPB, assuming that a higher degree of transparency, immutability of data, and more detailed information on the sustainability traits of the product facilitated through blockchain technology provide an added value for consumers [16,17]. Specifically, this study pursues three objectives: (1) to identify the psychological and sociodemographic antecedents of intention to buy and WtP for blockchain-enabled sustainability-certified coffee within an extended TPB framework; (2) to examine the underlying mechanisms through which trust, environmental beliefs, social norms, and perceived control shape consumer value perception of technology-enabled certifications; and (3) to identify and characterize distinct consumer segments with respect to their adoption profiles and WtP levels, thereby providing differentiated insights for industry stakeholders. Importantly, the study also examines whether blockchain-specific variables (trust in technology and certification) constitute distinct drivers of consumer behavior, or whether behavioral outcomes are primarily shaped by generic TPB mechanisms. The standard TPB, while well-established for predicting behavioral intentions, was designed for familiar, habitual behaviors and does not inherently account for the uncertainty associated with novel technologies or the moral beliefs that drive sustainable consumption. In the context of blockchain-enabled certification, consumers face both a technological novelty (requiring trust as a prerequisite for engagement) and a sustainability value judgment (requiring environmental beliefs as a motivational foundation). Standard TPB constructs (attitude, SN, and PBC) are insufficient to capture these domain-specific mechanisms. Therefore, following established extensions in technology adoption [18] and sustainable consumption research [19,20], trust and environmental beliefs are incorporated as theoretically justified additional constructs [21]. These assumptions are examined via an online survey among 400 German coffee consumers and evaluated using structural equation modeling and cluster analysis to identify distinct consumer segments. At the superordinate level, this study adds to the scarce body of literature exploring consumers' views on blockchain-enabled traceability solutions in supply chains and sustainability, helping actors in the coffee value chain gain insights and inspiration for business improvement.This study is both timely and contextually grounded. From a temporal perspective, blockchain technology has only recently moved from conceptual discussion to practical deployment in agri-food supply chains, yet consumer-side evidence, particularly on WtP, remains scarce and fragmented [12,22]. From a geographic perspective, Germany is Europe's largest coffee-import hub and one of the top ten coffee-consuming countries globally [23,24], yet no study to date has examined German consumers' perceptions of blockchain-enabled certification in this sector. From a theoretical perspective, existing TPB applications in similar contexts have either omitted trust [25] or environmental concern [20] as constructs or have relied on simpler regression-based approaches rather than SEM [21]. By combining both extensions in a covariance-based SEM (CB-SEM) framework with a large, population-comparable German sample, this study fills a specific gap at the intersection of blockchain adoption, sustainable consumption, and consumer behavior research.

In the next sections, recent and relevant literature on the topic is presented (Section 2), the research goals are specified in Section 2, and an overview of the approach, materials, and methods applied in the research is provided (Section 3). Next, the findings and limitations of the consumer study are presented (Section 4) and discussed (Section 5). The paper closes with a summary of the key insights, implications for the coffee industry, and suggestions for future research (Section 6).

2. Literature Review

The following section presents related work on blockchain technology in coffee value chains for sustainability and consumer perception, thereby outlining the research gap addressed in this study. In the second part, factors influencing consumer WtP for blockchain-certified coffee. Additionally, based on the identified research gap, we motivate our hypotheses.

2.1. Willingness-to-Pay for Sustainable Coffee Certification

Additionally, advancements in consumer research related to sustainability certification reveal varying levels of consumer awareness and WtP for sustainable coffee. Ref. [26] conducted a choice experiment in Spain that indicates strong preferences for organic and UTZ (now Rainforest Alliance) certifications, reinforcing the notion that consumers are willing to invest in products that assure sustainability. However, their study unexpectedly observed a negative price premium for Fairtrade-certified coffee, contradicting previous findings, such as ref. [27] showing for the Italian market a price premium of about 30%; ref. [28] showing in the German market a price premium of about 55%; and ref. [29] in the US market of about 15–30%. The findings of [26] could be explained by the low overall consumption of Fairtrade-certified products in the Spanish market. Uttah and Lee et al. confirmed a price premium of 25–30% for sustainable coffee versus conventional options based on consumer data [30].

Furthermore, ref. [31] adds depth with transferable insights to understanding consumer behavior in Asian markets. Their investigation into Taiwanese consumer preferences regarding coffee certification labels underscores a rising awareness of environmental issues, thereby encouraging producers to adopt blockchain for enhanced traceability and certification. Research by [32] indicates generational differences in perceptions of eco-labels, which help explain how these perceptions may influence consumer behavior toward blockchain-certified products versus traditional certification across different age groups.

In conclusion, research consistently indicates that consumers are willing to pay more for sustainable coffee options and that blockchain technology holds significant promise for enhancing sustainability certification in the coffee sector with an attractive price premium to be realized in retail.

2.2. Factors Affecting the Willingness-to-Pay for Sustainability Certification

The following section introduces the TPB and its relevance for this study. According to the TPB, which can be applied generally to explain individuals' behavior, this study argues that attitudes toward the behavior, SN, and PBC are factors affecting consumers' WtP for blockchain-enabled sustainability certification in the coffee value chain. The factors, as such, are determined by respective control beliefs. The TPB recognizes the influence of background factors, e.g., demographics, and allows for extension through additional influential factors such as trust or habits. According to the TPB, behavior is approximated by intention, which is often measured in studies where real-life behavior cannot be observed [16]. In a 2015 paper building on his original theory, Ajzen argues that the TPB is particularly fit for assessing consumers' planned behavior in food consumption-related decisions, because, unlike popular multi-attribute and subjective expected utility models popular in consumer research, which are looking at revealed preferences, the TPB directly examines the theoretical constructs underlying the decision model [17]. The TPB has been extended in numerous studies to account for domain-specific antecedents. In technology-driven adoption contexts, trust has been integrated as an additional construct to reflect consumers' uncertainty about novel systems [18,33,34]. In sustainable consumption contexts, environmental concern and moral norms have been shown to independently predict behavioral intention beyond the standard TPB constructs [19,20,35]. Studies combining both technology and sustainability dimensions, most notably Dionysis et al. [21] in a blockchain-coffee context and Denashurya et al. [36] in a palm oil certification setting, have validated the relevance of these extensions empirically, supporting their inclusion in the present study.

In the context of factors influencing consumers purchase decisions in food consumption, Ajzen emphasizes the relevance of background factors influencing purchase decisions in the updated theory. Ref. [36] examined how farmers' attitudes and behaviors toward the Indonesian Sustainable Palm Oil certification system influence sustainable palm oil practices, using the TPB, and emphasizes the need for positive attitudes and perceived control to adopt sustainable practices. Ref. [25] investigated consumer motivations regarding certified aquaculture products using TPB, effectively mapping attitudes, social norms, and PBC to purchase intentions. This study empirically verifies the relations within the TPB framework, which supports the relevance of these constructs in a certification context. Ref. [20] performed a study on motivations to buy green products by extending the TPB, highlighting the relevance of environmental concern and consumer innovativeness as antecedents of behavior. Environmental beliefs and concerns were also confirmed by other authors, who identify environmental concerns as significant predictors of sustainable consumption behavior, suggesting that integrating this variable into the TPB framework could enhance understanding of consumer motivations in the context of sustainability certifications [19,35]. Ref. [34] investigates the relationship between PBC and trust in fostering sustainable entrepreneurship, suggesting that these variables could significantly influence consumer willingness to engage in sustainable consumption behaviors.

Since the role of trust in blockchain-enabled sustainability certification has hardly been studied by researchers in the context of coffee and consumer research, justification for the inclusion of the variable has been drawn from [21], who performed a study on blockchain traceable organic coffee in a British context employing a TPB approach, and [33], who studied the role of blockchain for trust in the wine supply chain. To validate general trust in technologies and the reliability of blockchain in particular, two well-established item scales by [18] are selected for our study. Moreover, ref. [21] provided a general starting point for the questionnaire development, but the authors had adopted a simpler approach based on regression models. Ref. [37] explored the role of blockchain in enhancing consumer value in the beef industry, using a similar analytical approach as [21], yet highlighting the need for other researchers to consider methodologies such as structural equation modeling in this context. Our study takes guidance and insights from past research into account to build an approach, based on recent literature, a broader sampling approach, and structural equation modeling as an advanced analytical method.

In summary, the literature indicates that attitudes, SN, PBC, trust, and environmental beliefs are pivotal in shaping consumer intentions to purchase blockchain-enabled sustainability-certified coffee, but background factors, environmental beliefs or concerns, as well as trust in certification and blockchain technologies, need to be considered. Table 1 operationalizes each construct identified in the preceding theoretical discussion (Section 2), summarizing their definitions, roles within the extended TPB framework, and the item scales from which measurements were adapted. The extended model underlying the study is depicted in Figure 1. Item scales were taken from the existing literature and, if needed, adapted for better alignment with the context. The questionnaire and variables are available on Zenodo [38].

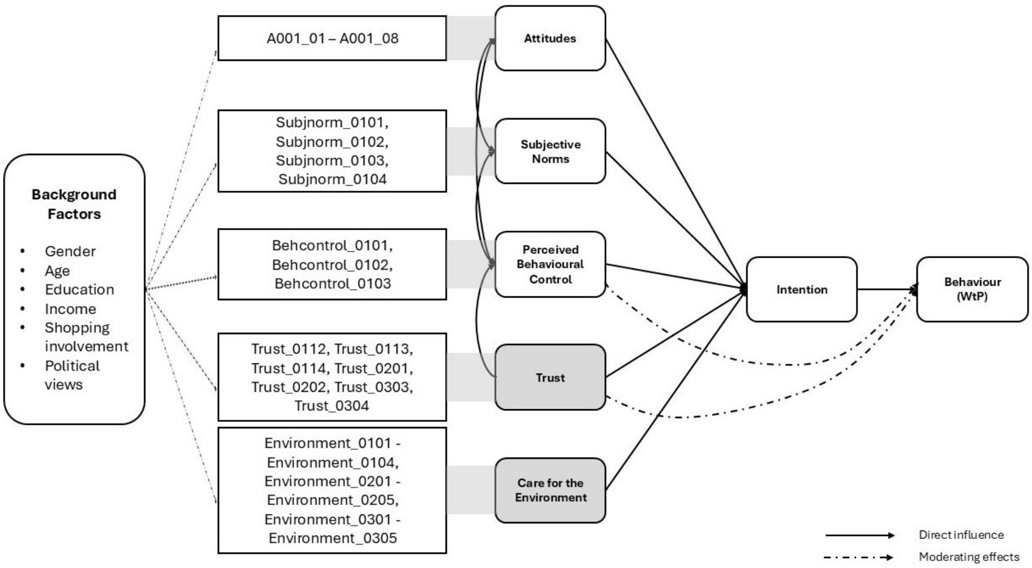

Figure 1. The extended TPB, based on Ajzen [17]. The gray–shaded constructs "Trust"and "Care for the Environment" have been added based on the literature review.

To contextualize the consumer study within the broader dynamics of the coffee value chain, this section briefly reviews the supply chain and producer-side literature on blockchain adoption. While the empirical study focuses exclusively on consumer behavior, this context motivates the need for consumer-side evidence on blockchain-enabled certification to complete the picture.

Table 1. Definition and measurement of variables to determine WtP for blockchain-enabled sustainability certification on coffee.

Variable	Meaning of Variable	Source of Variables/Items
Attitudes	Personal evaluation of the degree of approval or disapproval, satisfaction and dissatisfaction of purchasing coffee with blockchain-enabled sustainability certification.	Adapted after [21,36].
Subjective norms	Personal perceived social pressure to purchase coffee with blockchain-enabled sustainability certification.	Adapted after [20,21,31].
Perceived behavioral control	Personal prediction of the complexity or ease to find and evaluate the additional information provided via blockchain-enabled sustainability certification.	Adapted after [21,31,36].
Trust in blockchain-enabled sustainability certification	Individual's trust that the additional information provided by blockchain-enabled sustainability certification is authentic.	Adapted after [21,33]
Trust in technology	Individual's trust in technology in general and the reliability of blockchain technology in particular.	After [18].
Care for the environment	Individual's care for the environment and related environmental issues.	Adapted after [19,20,35].
Willingness-to-pay (WtP)	Respondent's self-reported willingness to pay a price premium for coffee with blockchain-enabled sustainability certification compared to a Fairtrade reference price.	Adapted after [1,30].

2.3. Blockchain in Coffee Supply Chains

Recent research has highlighted the transformational potential of blockchain technology for traceability, data management, production processes, food quality and safety in sustainable food supply chains [13,39]. The integration of blockchain into coffee supply chains brings forth increased transparency, traceability, and consumer trust, which are pivotal for fostering a sustainable market environment, but governance mechanisms must be carefully evaluated to avoid proliferation of existing power imbalances [40]. Samoggia et al. elaborate on how blockchain can cultivate fairness within agri-food chains, particularly emphasizing its implications for coffee products. Their study critically examines the transparency mechanisms that blockchain can facilitate to reinforce ethical practices in coffee sourcing [41].

Moreover, consumer willingness to engage with blockchain-traceable coffee has been investigated. Utilizing the theory of planned behavior, the authors assessed consumer intentions regarding blockchain-traceable coffee, revealing that attitudes towards environmental protection and trust significantly influence purchasing decisions, whilst habits were identified as non-relevant [21]. Their findings that consumers are increasingly driven by sustainability considerations align well with Huang et al., who investigated via a signalling theory-based approach that blockchain labels enhance perceived sustainability levels, thus increasing purchase intentions compared to traditional certification labels [22].

Ref. [14] discussed how blockchain facilitates ecologically embedded practices in coffee supply chains but noted the limited understanding of consumer integration into circular economies. Their qualitative case studies offer insights into how consumers perceive and utilize certifications associated with blockchain technology in making purchasing decisions. The study illustrates the importance of consumer engagement in the adoption of blockchain solutions for sustainable practices.

The preference for sustainable and organic production generally mirrors findings from [4], which explored coffee producers' perspectives on blockchain, highlighting perceived opportunities that align with consumer demand for certification transparency and sustainability. Taken together, these studies underscore both the transformative potential and the remaining uncertainties of blockchain adoption in the coffee sector, motivating a closer examination of the research gaps addressed in this study.

The current landscape of consumer research regarding blockchain-enabled sustainability certification in coffee reveals several critical research gaps. These gaps stem from the limitations in understanding the implications of blockchain technology on consumer perceptions, producer experiences, and the overall effectiveness of sustainability certifications.

Firstly, while blockchain technology shows promise for enhancing transparency and traceability in coffee supply chains, its actual impact on consumer purchase intentions remains inadequately explored. Research by [21] has identified consumer concerns around sustainability and fair trade but does not sufficiently examine how these concerns translate into behavioral intentions toward blockchain-traceable coffee. Further research is needed to examine specific consumer demographics and their varying responses to blockchain certification to provide a more nuanced understanding.

Additionally, scholarly work has pointed out that while blockchain can integrate sustainability improvements into supply chains, existing studies often overlook the complex socio-economic dynamics at play between producers and consumers. Ref. [4] highlighted the limited agency of coffee producers in global value chains due to systemic inequalities, suggesting that the benefits of blockchain could inadvertently deepen these disparities. This underscores the need for research focusing on the interaction of local producers with blockchain technology and how it affects their economic viability, alongside consumer perceptions.

Moreover, existing studies tend to emphasize either the technological aspects of blockchain or the ethical dimensions of sustainability certifications but rarely integrate both perspectives comprehensively. For instance, ref. [42] discussed the "veil of transparency" that blockchain can create, potentially obscuring underlying sustainability issues, without providing robust evidence of its practical implications on consumer trust and buying behavior. On the contrary, blockchain has been found to enable consumers' access to trustworthy product data and safeguard them against the greenwashing trap, significantly more than traditional certification systems [43]. Integrating insights from behavioral psychology with blockchain applications could be a fruitful area of exploration, highlighting how transparency affects consumer trust and purchasing decisions. While recent research has begun to address the efficacy of traditional sustainability certifications like Fairtrade, and those offered via blockchain, there remains a gap in assessing how consumers differentiate between these two types of certifications regarding their willingness to pay a premium.

Finally, the effectiveness of blockchain technology in addressing the socio-economic challenges faced by producers, particularly in terms of their bargaining power and market access, remains underexplored. Studies such as [44] argue that many certifications fail to adequately meet farmers' needs, highlighting a gap that could be addressed by examining how blockchain could reshape these power dynamics. The perception of the interplay between large coffee companies' blockchain adoption and the real-world benefits it provides to smallholder farmers warrants further systematic investigation. Collectively, these gaps indicate that prior research has either focused on technological potential or specific market contexts, but has not systematically examined the interplay of psychological, demographic, and economic factors shaping consumer WtP for blockchain-enabled certification in a major European market. This study directly addresses this gap.

In summary, the research gap in blockchain-enabled sustainability certification in coffee encompasses insufficient understanding of consumer behavior regarding blockchain transparency, the socio-economic dynamics affecting producers, the interplay between traditional and blockchain certifications, and the identification of practical benefits for producers in this realm.

Based on the literature and model design, the following hypotheses are derived for further investigation:

- H1: Compared to women, men have much stronger attitudes, SN, PBC, and intentions in favor of the subject. *Prior studies report mixed gender effects in sustainable consumption, with some evidence of women showing stronger pro-environmental orientations* [20,35].
- H2: Higher care for the environment results in higher intention and WtP. *Environmental concern has been identified as a consistent predictor of sustainable purchase intentions in food contexts* [19,21,35].
- H3: Higher trust in technology and blockchain increases the intention and WtP. *Trust in technology has been shown to facilitate adoption of novel digital solutions in food supply chains* [18,33].
- H4: Higher PBC will result in higher intention and WtP. *PBC is a core predictor of behavioral intention and WtP in TPB-based models* [16,25].
- H5: Higher perceived social pressure will result in higher intention but not necessarily in higher intention and WtP. *Subjective norms have been found to influence intention, particularly in social consumption contexts* [17,31].
- H6: A price premium can be obtained for coffee with blockchain-enabled sustainability certification compared to Fairtrade coffee. *Prior research indicates positive WtP premiums for sustainably certified coffee ranging from 15% to 55%* [28,29].

3. Materials and Methods

The following section provides an overview of the research procedure and analysis.

3.1. Procedure and Sample

Based on the theoretical TPB mode, an online survey was developed. A two-stage pretest with twelve participants was conducted in English and German, testing a "pen-and-paper" version for first improvements, and the online version in the second round. The survey was administered in SoSciSurvey (SoSci Survey GmbH, Erchanbertstraße 6, 81929 München, Germany) and distributed via a professional survey platform (moweb research GmbH, Mertensgasse 12, 40213 Düsseldorf, Germany) running verified panels and included participant incentivation. Data were collected over two weeks in September 2025. The survey was completely consensual and anonymous, open to individuals above

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18 years of age in Germany. Germany serves as a suitable geography for the survey, as it is not only the largest coffee import hub in Europe [23], but also among the top ten coffee-consuming countries globally [24]. The sample size was determined based on the survey length and model complexity, targeting n = 400 which was reached. Quotas on age, gender, and occupation were applied to ensure a spread of participants comparable to the German population. In addition to the TPB constructs detailed in Table 1, political orientation was assessed to examine whether political views moderate TPB construct scores. To ensure a common baseline understanding, all participants were presented with a standardized conceptual explanation of blockchain-enabled sustainability certification in the coffee context as part of the main questionnaire body. This explanation described blockchain as a decentralized, tamper-proof digital ledger that records each step of the supply chain, enabling real-time verification of sustainability claims. The explanation was developed and validated during the two-stage pretest to ensure comprehensibility across educational backgrounds. The questionnaire, data set, and code are available on Zenodo [38].

3.2. Data Analysis

For data processing in this research, structural equation modeling (SEM) was employed, which is a powerful tool for data analysis but also sensitive to sample size [45]. For the analysis, the Python semopy 2.3.11 package was used due to its support of declarative model specifications and advanced parameter estimation features [46,47]. All measurement scales were adapted from validated instruments in prior literature (cf. Table 1: Attitude items were adapted from Dionysis et al. [21] and Denashurya et al. [36]; Subjective Norm and PBC items from Dionysis et al. [21], Liu et al. [31], and Kamalanon et al. [20]; Trust in certification items from Dionysis et al. [21] and Fani et al. [33]; Trust in technology items from McKnight et al. [18]; Environmental Concern items from Li et al. [19], Kamalanon et al. [20], and Zeng et al. [35]; and WtP items from Ut-tha et al. [30] and van Loo et al. [1]. All adaptations are documented in the questionnaire available on Zenodo [38]. Since the TPB is well-established, CB-SEM was chosen, as it directly tests how well the covariance structure implied by the theoretical model fits the observed data. Before fitting the SEM in a multi-step approach, a test for multivariate normality of the data was performed to validate the assumptions underlying maximum likelihood estimation commonly used in SEM. This included an assessment of skewness and kurtosis for all variables and application of formal tests for multivariate normality. In the first step, the quality criteria of the measurement model were assessed.

While the core TPB constructs follow the well-established Ajzen framework, several item scales in this study were adapted from their original sources or newly assembled for the blockchain-certification context. Under these conditions, EFA is methodologically appropriate prior to CFA, as it allows an empirical assessment of the factor structure without imposing constraints, thereby identifying potential item misspecifications before they propagate into the confirmatory stage [45]. This two-step approach (EFA followed by CFA) follows the measurement model development protocol recommended by Anderson and Gerbing and is particularly warranted when construct boundaries may overlap, as is the case here for PBC, Trust, and Environmental Concern [48]. This approach identifies the underlying factor structure that best explains the observed covariance among items and is particularly suitable when adapting or newly assembling measurement scales. Subsequently, a confirmatory factor analysis (CFA) was conducted, guided by theoretically anticipated factor structure, to optimize the factor configuration established during the EFA and test hypotheses regarding model fit.

The adequacy of the measurement model was assessed using indicators and cut-off values widely recommended by the international literature. Specifically, internal consistency was evaluated by Cronbach's alpha ($\alpha > 0.7$), and composite reliability (CR > 0.7) was determined for each construct [49,50]. Convergent validity was tested using the average variance extracted (AVE) (AVE > 0.5), while discriminant validity was checked by requiring the maximum shared variance (MSV) to be less than the AVE [51]. Discriminant validity was further verified by the Fornell and Larcker criterion [52], which requires that the square root of AVE for each construct exceeds its correlations with other constructs, and by the Heterotrait–Monotrait (HTMT) ratio [53], where each value must not exceed 0.85.

In the second step, The overall fit of the structural model was evaluated overall model fit was assessed using standard fit indices including Chi², *p*-value, CFI, TLI, RMSEA, GFI, and normed fit index (NFI), along with AIC and BIC for model comparison. An absolute fit requires $p > 0.05$ and $\chi^2/\text{df} < 3$. goodness of fit index (GFI), comparative fit index (CFI), and Tucker–Lewis Index (TLI) were considered excellent if >0.95 or acceptable if >0.90. Root mean square error of approximation (RMSEA) was considered excellent if <0.06 and acceptable if <0.08 [54]. The Akaike information criterion (AIC) and Bayesian information criterion (BIC) hold information about model comparison, not absolute fit. A lower AIC and BIC is considered better, as model complexity is punished [45,55,56].

As all measures were collected from the same respondents in a single survey session, common method bias (CMB) was assessed using two post hoc indicators. First, Harman's single factor test was applied. An unrotated exploratory factor analysis yielded a first factor explaining 50.3% of total variance, marginally exceeding the critical threshold of 50%, which cannot fully rule out CMB as a concern [57]. Second, a more rigorous SEM-based test was conducted by estimating a single-factor baseline model and comparing its fit to the theoretical measurement model. The single-factor model showed substantially worse fit (CFI = 0.630, RMSEA = 0.110) compared to the theoretically specified measurement model (CFI = 0.900, RMSEA = 0.069), indicating that the observed covariance structure is not adequately explained by a single common method factor [58]. Taken together, while CMB cannot be entirely excluded, the SEM-based comparison provides evidence that it is unlikely to critically distort the structural results. CMB nonetheless remains an inherent limitation of the cross-sectional single-respondent design and is acknowledged as such.

In the third step, the full structural model was constructed and estimated using semopy 2.3.11, which implements maximum likelihood estimation. The relationships between latent variables were examined by evaluating global model fit indices and theory-driven diagnostics to assess potential areas of model misfit. Additionally, effects were re-estimated using a bootstrapping procedure (2.000 iterations, 95% confidence intervals) to assess the significance and stability of effects, following best practice guidelines. To account for differences in decision-making patterns outside the socio-demographic variables, a k-means cluster analysis was performed based on the standardized latent construct scores derived from the SEM. The optimal number of clusters was determined using the elbow method, subsequently confirmed by silhouette analysis. This approach enables the identification of psychographically distinct consumer segments that complement the results of the structural model.

During the preparation of this work, the authors used ChatGPT-5.5 (ChatGPT: OpenAI Headquarters, 1455 3rd Street, San Francisco, CA 94158, USA) to support the Python coding process and Grammarly to ensure correct spelling and Grammar.

4. Results

In the following section, the results are presented, providing an overview of the sample first, then presenting the univariate statistics, outcomes of EFA, CFA, and its optimization, and then the SEM. Further,the results of the cluster providing additional insights on psychographic characteristics of subgroups in the sample are presented.

4.1. Descriptive Statistics

Table 2 provides an overview on the sample characteristics and references to the German population. The sample was recruited with a quota sampling system to provide a non-representative but comparable representation of the German population, which was achieved. Therefore, the data can be considered indicative of the German population, providing insights into different consumer groups. Some deviations can be explained by the lack of a formally representative sample size and reference values stemming from other years than the year 2025, when the study was conducted.

Table 2. Description of the sample.

Variable	Variable Expression	Sample	Germany	Reference
Gender	male, female, non-binary, other, prefer not to say	male 50.5%/female 49.5%	male 49.2%/female 50.8%	[59]
Age	18–29 years, 30–39 years, 40–49 years, 50–59 years, 60–69 years, 70+ years	18–29 years 16.50%, 30–39 years 18.25%, 40–49 years 17.25%, 50–59 years 20.75%, 60–69 years 18.50%, 70+ years 8.75%	<18 years 16.7%, 18–29 years 12.9%, 30–49 years 25.2%, 50–64 years 22.9%, 65+ years 12.2%	[60]
Education	(1) Vocational preparation or no formal school degree, (2) basic secondary education or vocational school or lower secondary school certificate, (3) Intermediate vocational training or intermediate school certificate, (4) advanced vocational training or technical diploma or general university entrance qualification, (5) Specialist or technician, (6) Master craftsperson or business administrator or bachelor's degree, (7) Master's degree or advanced business qualifications, (8) Doctorate or postdoctoral qualification (habilitation), (9) prefer not to say	(1) 3.25%, (2) 5.00%, (3) 13.00%, (4) 36.25%, (5) 4.00%, (6) 15.00%, (7) 16.50%, (8) 6.00%, (9) 1.00%	(1) 25.00%, (2) 46.60%, (3–5) 9.30%, (6) 2.60%, (7) 14.70%, (8) 1.20%	[61]
Living situation	(1) Living alone, (2) in partnership with shared household, (3) With children as a family, (4) In shared accommodation, (5) With parents or family of origin, (6) Other form of housing	(1) 28.75%, (2) 37.50%, (3) 26.25%, (4) 1.25%, (5) 4.50%, (6) 1.75%	(1) 41.6%, (2) 28.3%, (3) 28.7%, (4) 5.5%, (5) 4.00%, (6) -no direct comparison	[62,63]
Occupation	(1) Employed full-time, (2) Employed part-time, (3) Self-employed, (4) Freelance professional (e.g., doctor, lawyer, etc.), (5) Unemployed, (6) Student or in vocational training, (7) not specified	(1) 61.00%, (2) 19.00%, (3) 6.25%, (4) 3.25%, (5) 6.25%, (6) 3.00%, (7) 1.25%	–	–
Responsibility for grocery shopping	(1) Mainly responsible, (2) Equally shared with other household members, (3) Rarely responsible, (4) Never responsible	(1) 72.50%, (2) 25.00%, (3) 2.50%, (4) 0%	–	–
Coffee consumption (cups/day)	–	Median: 3, Mode: 3, Arithmetic mean: 4	3.4 cups	[64]

The sample is comparable to the German population with regard to gender and age distribution. Despite offering the possibility to choose other genders than male and female, there were only respondents identifying as either female or male in the sample. Participation in the survey was open to people above 18 years of age. 52% of the respondents are up to 49 years old, comparable to the German population, which has 54.8% of residents up to 49 years of age. The sample holds more people with a higher degree of education than the average German population. The living situation shows an under-representation of single-households in the sample, and an over-representation of shared households without children. Other forms of living are comparable in size, despite differing definitions of the categories. More than half of the participants is working full-time in an employed work setup, and another fifth of the sample are working part-time. Close to 10% are self-employed or freelancers, and the remaining are unemployed, studying, in training, or did not disclose their status. The percentage of unemployed people in the sample is comparable to the unemployment rate in Germany in 2025 [65]. The vast majority of respondents (72.5%) is mainly responsible for grocery shopping in their household, an 25% share the responsibility with another household member. The coffee consumption is comparable with the average coffee consumption, measured in cups per day, in Germany.

General knowledge on blockchain: Among the participants, 61.5% had heard about blockchain before, and more than half of the participants who had heard about blockchain (56.25%) know it for its potential use for traceability. Without initial priming, 52.25% of respondents stated that they trust in blockchain, of which 21.5% indicated previously that they had not heard about blockchain before. Further, 28.5% of respondents are unsure whether they trust blockchain technology or not, and 19.25% stated they do not trust the technology. Again, without priming the question, whether the respondent was willing to pay a premium for a product involving blockchain-enabled sustainability certification, a heterogeneous picture was shown. Table 3 summarizes the results.

Table 3. Share of responses to statements on blockchain-enabled sustainability certification (n = 400).

Statement	Share of Responses
I am willing to pay more for blockchain-enabled sustainability certification... ... in general	15%
... if environmental topics are supported in particular	24%
... if social topics are supported in particular	12%
... if economic and governance topics are supported in particular	7%
I do not value sustainability certifications in general	21%
I am not willing to pay more, compared to other sustainability certifications	21%

Care for sustainability certification in coffee: When asked about their attention on sustainability labels when purchasing coffee, 28% of the respondents shared that they focus on sustainability labels when buying coffee more, compared to other product categories, and 47% stated that they focus on sustainability labels in the same way as in other product categories. Among respondents, 20% do not pay attention to sustainability labels when buying coffee, and 6% stated they focus less on sustainability labels when buying coffee than in other product categories. Sustainability labels were considered useful by 77% of respondents, and the information they convey was considered helpful by 72%. Before starting the main body of the questionnaire, participants were shown a brief conceptual explanation of coffee with blockchain-enabled sustainability certification.

4.2. Structural Equation Modeling

The SEM analysis follows a sequential, theory-driven protocol comprising four stages: (1) assessment of univariate statistics and factorability; (2) exploratory factor analysis (EFA) to empirically verify the item-construct structure; (3) confirmatory factor analysis (CFA) to evaluate measurement model quality; and (4) structural model estimation with bootstrapping. Each stage is presented in turn below.

4.2.1. Univariate Statistics and Factorability

Prior to conducting the SEM, univariate statistics were examined for all items. Skewness values ranged from −1.30 to 0.50, and kurtosis values ranged from −0.98 to 1.46, with only three items (Environment_0201–Environment_204) showing slightly negative skewness exceeding $|1|$. Overall, the distributions of all items were within acceptable limits, indicating no substantial deviation from normality. No extreme values were present, and all items exhibited variability across the full response scale (1–7). Correlation diagnostics indicated the absence of multicollinearity, as no near-perfectly correlated item pairs were identified, and no constant items were present. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was excellent for the dataset overall (KMO = 0.965) and predominantly high for individual items (>0.9), confirming that the data were suitable for factor-based modeling. The smallest eigenvalue of the correlation matrix was 0.084, indicating sufficient variance and no issues with singularity.

Taken together, these results suggest that the data meet the assumptions necessary for reliable SEM analysis. A summary of skewness, kurtosis, and KMO values per item is provided in the Appendix (ref. Table A1).

In the next step, the factorability of each construct was assessed using Bartlett's test of sphericity and KMO measure of sampling adequacy. Bartlett's test was highly significant for all constructs ($p < 0.001$), indicating that the correlations between items were sufficiently different from zero and that factor analysis was appropriate. KMO values ranged from 0.733 to 0.956, demonstrating good to excellent sampling adequacy across constructs. Specifically, Attitude (8 items) and Trust (9 items) exhibited excellent KMO values above 0.91, while constructs with smaller item sets, such as PBC1 (3 items) and Env2 (5 items), showed acceptable KMO values above 0.73. These results confirm that all constructs included a sufficient number of valid, interrelated items suitable for factor-based modeling. The smallest eigenvalue of the item correlation matrix was 0.084, indicating that no items were perfectly collinear and that the correlation matrix was suitable for factor-based modeling and SEM estimation. A summary of skewness, kurtosis, and KMO values per item is provided in the Appendix (ref. Table A2).

4.2.2. Exploratory Factor Analysis

A screeplot was used to determine the number of factors to aim for in the EFA, indicating an ideal number of six factors in total (c.f. Figure 2).

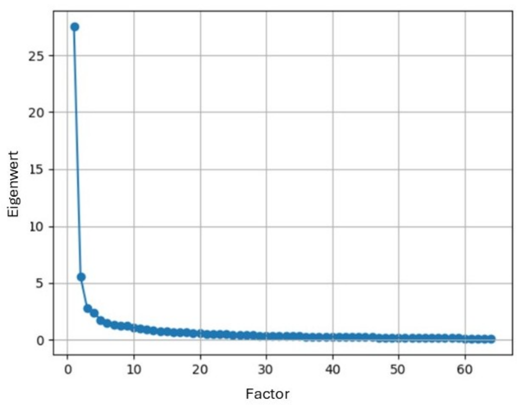

Figure 2. Screeplot determining target number of clusters in EFA.

An exploratory factor analysis was conducted to examine the underlying structure of the measurement items. The results revealed a clear factor structure, with most items loading strongly on their intended constructs and only minor cross-loadings (see Figure 1). Attitude items (Attitude_01 to Attitude_08) exhibited consistently high loadings on a single factor, ranging from 0.783 to 0.848, indicating a coherent and unidimensional factor. Environmental items displayed a more complex pattern, with Environment_0101 to Environment_0104 loading primarily on the first factor (0.751–0.809), Environment_0202 to Environment_0204 loading on the second factor (0.737–0.742), and Environment_0201 and Environment_0205 on the third factor (−0.623 and −0.709, respectively), suggesting the presence of distinct environmental subdimensions. Behavioral control items generally loaded on the first factor, although some items exhibited secondary loadings on a separate factor (0.470–0.556), reflecting a dominant general factor with minor subfactor structure. Political norm items loaded primarily on a separate factor (0.649–0.708), indicating a well-defined but moderately complex factor, while subjective norm items demonstrated coherent loadings on the primary factor (0.620–0.727). Trust items loaded mainly on the first factor (0.710–0.762), with a few items showing moderate secondary loadings on additional factors, and the intention/WtP items showed moderate loadings on two factors (0.438 and 0.509), indicating a partial association with multiple factors. Overall, the EFA results support the hypothesized construct structure, with most items exhibiting strong primary loadings and only minor cross-loadings, providing evidence for construct validity and justifying subsequent confirmatory factor analysis and structural equation modeling.

4.2.3. Confirmatory Factor Analysis

A multi-step confirmatory factor analysis (CFA) was conducted to evaluate the measurement model. In the initial CFA, all hypothesized items were included, and standardized factor loadings were examined. Most items demonstrated strong loadings on their intended constructs, with estimates ranging from 0.596 to 0.907 for Attitude, Trust, and Politics constructs, although several items exhibited low loadings or negative estimates, indicating potential issues with reliability or construct representation. Cronbach's alpha values for the constructs ranged from 0.551 (Politics) to 0.928 (Env1), highlighting that some factors, particularly Politics, had relatively low internal consistency in the initial model. Model fit indices suggested a moderate fit, with a chi-square of 5883.53 (df = 1674, $p < 0.001$), CFI = 0.811, GFI = 0.755, adjusted goodness of fit index (AGFI) = 0.741, TLI = 0.800. and RMSEA = 0.079, indicating the need for model refinement.

Based on these results, an optimization procedure was applied. Items with standardized loadings below 0.4 and items whose removal would improve Cronbach's alpha were identified as candidates for exclusion. The optimization followed a sequential decision rule: in a first step, items with standardized factor loadings below 0.40 were flagged for removal, as they indicate insufficient construct representation [45]. In a second step, among the remaining borderline items, those whose removal would increase Cronbach's alpha by at least 0.02 were also excluded to improve internal consistency. Items were removed one at a time, with model re-estimation after each removal. No items were removed solely based on modification indices, in order to preserve theoretical specification integrity. This procedure resulted in the removal of five items: Trust_0203, Politic_0104, Politic_0202, Politic_0204, and Behcontrol_0203.

The final, optimized CFA demonstrated a substantially improved model fit. Standardized factor loadings for the retained items were generally strong, ranging from 0.283 to 0.907, and all were statistically significant ($p < 0.001$), with minor exceptions for items retained to maintain construct coverage. Overall model fit improved notably, with a chi-square of 2771.82 (df = 953, $p < 0.001$), CFI = 0.900. GFI = 0.856, AGFI = 0.843, TLI = 0.891, and RMSEA = 0.069, indicating an acceptable fit according to conventional guidelines. These results provide evidence for the validity and reliability of the optimized measurement model and justify its use in subsequent structural equation modeling.

While composite reliability and convergent validity (AVE) were largely satisfactory, discriminant validity was partially compromised among constructs related to PBC, environmental concern, and trust. Discriminant validity was partially compromised for Trust, PBC2, and Env1, where AVE falls below MSV, a standard warning sign for construct overlap that cannot be dismissed as merely theoretical. This represents a genuine methodological limitation: the observed overlap between PBC, environmental concern, and institutional trust constructs may reflect shared variance that the measurement model cannot fully disentangle. Consequently, path coefficients involving these constructs should be interpreted with caution. The Politics construct additionally exhibited AVE below 0.50, which falls below the Fornell–Larcker threshold for convergent validity; while CR exceeds 0.70, this construct's validity is limited. These constructs were retained due to their theoretical importance and distinct roles in the structural model, but the limitations are explicitly acknowledged here and in the limitations section. The full results are provided in Table 4.

Table 4. Assessment of convergent and discriminant validity.

Construct	AVE	CR	MSV	AVE > MSV	Validity
Attitude	0.762 **	0.938 **	0.734	Yes	Valid
Trust	0.650 **	0.927 **	0.822	No	Limited: AVE < MSV
Politics	0.479 †	0.807 **	0.448	Yes	Convergent validity limited
Subjnorm	0.752 **	0.924 **	0.567	Yes	Valid
PBC1	0.798 **	0.922 **	0.619	Yes	Valid
PBC2	0.682 **	0.937 **	0.870	No	Limited: AVE < MSV
Env1	0.770 **	0.931 **	0.870	No	Limited: AVE < MSV
Env2	0.593 **	0.844 **	0.547	Yes	Valid
Env3	0.669 **	0.889 **	0.547	Yes	Valid

Notes. AVE = average variance extracted; CR = composite reliability; MSV = maximum shared variance. ** AVE $\geq$ 0.50/CR $\geq$ 0.70 (recommended threshold). † AVE $<$ 0.50 but CR $>$ 0.70; convergent validity considered acceptable. Discriminant validity is supported when AVE exceeds MSV [52].

4.2.4. Structural Equation Modeling

Structural equation models were estimated using intention to buy and WtP for blockchain-certified sustainable coffee as dependent variables. The full model estimation procedure, code, and results are available on Zenodo [38]. *Traditional TPB model:* In a first step, the traditional TPB model was estimated separately for each of the two target variables. Both models show comparable and acceptable fits given their strict theory-driven specifications. In the traditional TPB specification, PBC emerged as the only significant predictor of intention, whereas WtP was driven by both SN and PBC (c.f. Table 5). Political orientation strongly shapes attitudes, perceived norms, and PBC, yet its influence on *intention* remains fully mediated through the TPB core constructs, indicating no direct effect on behavioral intention or WtP. Sociodemographic effects were treated as quasi-metric, as they had been measured in logically robust scales. They are secondary and mainly operate through perceived control rather than directly shaping intention. It should be noted that CFI and TLI values fall slightly below the conventional 0.90 threshold in both models. This is a genuine limitation of the current model specification. Three factors partly mitigate the concern: first, chi-square statistics are known to be sensitive to sample size, tending toward rejection even for minor misspecifications with sample sizes larger than 300 [45]; second, RMSEA values remain below or near 0.08 in both models, indicating acceptable approximate fit [54]; and third, the absence of post hoc modifications ensures theoretical integrity at the cost of statistical optimization. Readers should interpret path coefficients with appropriate caution, given these fit limitations (c.f. Table 6).

Table 5. Relevant path coefficients for both traditional models.

Path	β (WtP)	β (Intention)	Interpretation
Attitude	−0.040 (n.s.)	0.110 (n.s.)	No direct effect
Subjnorm	0.379 *	0.091 (n.s.)	Only relevant for WtP
PBC1	−0.085 (n.s.)	0.083 (n.s.)	No effect
PBC2	0.328 *	0.322 *	Relevant for both outcomes

Notes. Standardized path coefficients (β) are reported. * $p < 0.05$; n.s. = not significant.

Table 6. Global fit indices for the traditional TPB models.

Fit Index	Reference Value	TPB (Intention)	TPB (WtP)
χ^2	small	1715.22	1812.64
p-value (χ^2)	>0.05	0.000	0.000
TLI	>0.90	0.869	0.860
RMSEA	<0.08	0.0805	0.0837
NFI	>0.90	0.845	0.838
GFI	>0.90	0.845	0.838
CFI	>0.90	0.883	0.875
AIC	small	157.42	156.94
BIC	small	488.72	488.23

Notes: Lower values of χ^2, RMSEA, AIC, and BIC indicate better model fit, whereas higher values of CFI, TLI, NFI, and GFI indicate superior fit.

Extended TPB: Next, the model was re-estimated, extending the model by *environmental concerns* and *trust* as predictors of intention and WtP. The model targeting intention showed slightly better overall model fit, WtP was explained by a small, yet theoretically consistent set of predictors (c.f. Table 7). In the next step, the same model was calculated but using the reported intention to pay more (Intention_01) as the target variable. The model showed that moral approval and environmental concern translate into intention, whereas actual economic commitment requires additional social and control-related mechanisms (c.f. Table 8).

Bootstrap resampling (n = 2.000) for all four model variations confirmed the stability of the SEM estimates. For the extended model, the main influence of environmental aspects on intention was confirmed. However, the bootstrapping results also show significant effects of Env2 and Env3, which suggests possible uncertainties in the estimation. Overall, the bootstrap confidence intervals support the theoretical interpretation of the SEM results. Although the CFI falls slightly below the commonly suggested cut-off value of 0.90, other fit indices indicate an acceptable model fit. As discussed for the traditional model, chi-square sensitivity at n = 400 and the absence of post hoc modifications partly explain this result and the RMSEA of 0.075 remains below 0.08 [54]. Comparing both models, the results show that WtP is primarily explained through social norms and PBC, as shown in both the traditional and the extended TPB model. Intention can be explained by PBC when only the traditional TPB elements are considered, but environmental beliefs emerge as even more important predictors of intention when introduced to the model. For economic commitment (WtP), the setting of social norms is essential.

Table 7. Global fit indices for the extended TPB models.

Fit Index	Reference Value	Ext. TPB (Intention)	Ext. TPB (WtP)
χ^2	small	3880.21	4024.72
p-value (χ^2)	>0.05	0.000	0.000
TLI	>0.90	0.846	0.839
RMSEA	<0.08	0.0735	0.0755
NFI	>0.90	0.806	0.800
GFI	>0.90	0.806	0.800
CFI	>0.90	0.858	0.851
AIC	small	278.60	277.88
BIC	small	873.33	872.60

Notes: Lower values of χ^2, RMSEA, AIC, and BIC indicate better model fit, whereas higher values of CFI, TLI, NFI, and GFI indicate superior fit.

https://doi.org/10.3390/su18105159

Table 8. Relevant path coefficients for both extended models.

Path	β (WtP)	β (Intention)	Interpretation
Attitude	−0.095 (n.s.)	0.099 (n.s.)	No direct effect
Trust	0.008 (n.s.)	−0.042 (n.s.)	Irrelevant
Subjnorm	0.294 *	0.068 (n.s.)	Only relevant for WtP
PBC1	−0.074 (n.s.)	0.070 (n.s.)	No effect
PBC2	0.524 *	0.115 (n.s.)	Only relevant for WtP
Env1	−0.103 (n.s.)	0.319 *	Only relevant for intention

Notes: Standardized path coefficients (β) are reported. * $p < 0.05$; n.s. = not significant.

With regard to the hypotheses stated in Section 2, the following Table 9 indicates which hypotheses were supported, partially supported, or not supported. The detailed interpretation of these results is presented in Section 5.

Table 9. Summary of hypothesis evaluation.

H	Predictor	Outcome	Result
H1	Gender	Attitudes, SN, PBC, Intention	Not supported
H2	Environmental concern	Intention/WtP	Partially supported (Intention only)
H3	Trust in technology	Intention/WtP	Not supported
H4	PBC	Intention/WtP	Supported
H5	Subjective norms	Intention/WtP	Partially supported (WtP only)
H6	Price premium feasibility	WtP	Supported

4.3. Robustness Checks

To validate the robustness of the structural conclusions, three complementary analyses were conducted.

First, the structural model was re-estimated using component-based partial least squares SEM (PLS-SEM, Python package `plspm` 0.5.7) with more than 2000 bootstrap samples for the WtP model and for the Intention_01 model, each. The PLS-SEM goodness of fit reached 0.445 for the WtP model and 0.441 for the Intention_01 model—both above the 0.36 "large effect" threshold of Wetzels et al. [66]. The substantive structural conclusions were reproduced: Subjective Norm ($\beta = 0.192$, 95 % CI $[0.086, 0.306]$, $p = 0.001$) and PBC2 ($\beta = 0.310$, 95 % CI $[0.136, 0.495]$, $p = 0.001$) remained the dominant significant predictors of WtP, while Env1 was the dominant significant predictor of Intention_01 ($\beta = 0.234$, 95 % CI $[0.017, 0.439]$, $p = 0.032$). Trust remained non-significant on both outcomes. Effect magnitudes are systematically smaller in PLS-SEM than in CB-SEM, as expected, because CB-SEM corrects measurement error explicitly, but the direction, significance, verdict, and ordering of effect sizes are unchanged.

Second, the structural model was re-estimated three times after sequentially excluding the constructs flagged by AVE $<$ MSV (Trust, PBC2, Env1, in turn). Subjective Norm ($\beta \approx 0.30$) and PBC2 ($\beta \approx 0.36$) remained stable, significant predictors of WtP across all variants in which they were included, and Env1 ($\beta \approx 0.27$) and Attitude ($\beta \approx 0.12$) remained stable, significant predictors of Intention_01. When one of the highly correlated constructs was excluded, an adjacent construct partially absorbed its explanatory power (Env1 $\rightarrow$ WtP becomes 0.144, $p = 0.003$ when PBC2 is dropped; PBC2 $\rightarrow$ Intention rises from 0.143 to 0.277 when Env1 is dropped), consistent with construct overlap. Critically, no substantive conclusion of the paper depends on attributing the effect to one construct uniquely.

Third, an unmeasured common latent factor (CLF) was added to the optimized CFA following Podsakoff et al. [57] and Williams & McGonagle [67]. The CLF accounted for, on average, 4.8% of the indicator variance (median 1.6%), well below the 10 % lenient and 25% strict concern thresholds; standardized substantive loadings remained essentially unchanged (mean $|\Delta\beta| = 0.023$). A subset of the Env2 sub-scale items showed elevated method-variance shares with consistent negative method-factor loadings; this pattern reflects residual heterogeneity within the Env2 construct (consistent with its comparatively low AVE $= 0.593$) rather than a broad common-methods artifact or a negative-keying methods effect. Detailed bootstrap tables, drop-and-re-estimate path-coefficient tables, and the full CLF output are provided in the Zenodo repository [38].

4.4. Cluster Analysis

To identify distinct segments of consumers with respect to blockchain-certified coffee, a cluster analysis was conducted based on the standardized latent construct scores (Attitude, Trust, Politic, SN, PBC1, PBC2, and Environmental Concerns). The optimal number of clusters was determined using the elbow method and subsequently confirmed by silhouette analysis, both indicating a three-cluster solution (c.f. Figure 3). The cluster labels used below are illustrative summaries intended to aid interpretation; they do not imply a full characterization of the underlying consumer profiles. The mean silhouette score for the three-cluster solution was 0.26, which indicates a weak to moderate cluster structure. While the highest silhouette score was observed for k = 2 (0.332), the elbow criterion suggested a three-cluster solution. Together, the elbow method and silhouette analysis converge to three clusters. The relatively modest silhouette score suggests that cluster boundaries are not sharply defined and that the segmentation should be treated as exploratory and descriptive rather than definitive. Nevertheless, the three-cluster solution was retained because it provided a more differentiated and interpretable segmentation of consumer groups, consistent with the exploratory nature of this study.

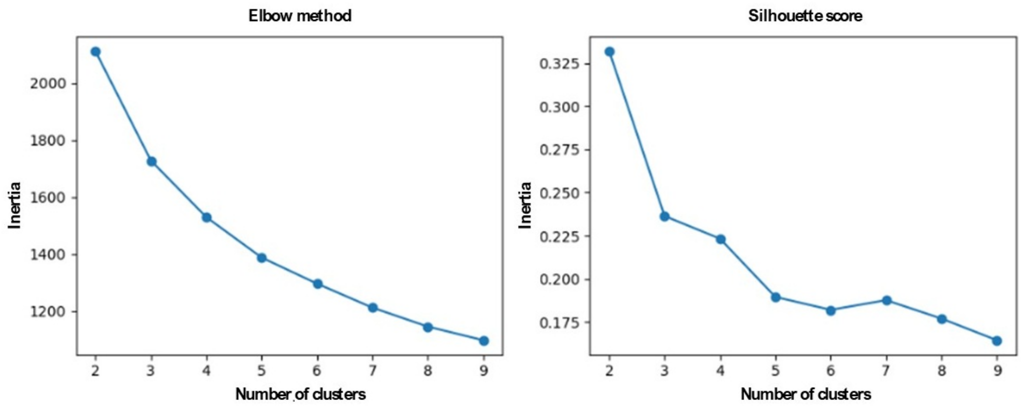

Figure 3. Determination of the appropriate number of clusters using elbow method and silhouette score.

The final cluster solution comprised all 400 respondents and resulted in three clearly distinguishable segments of meaningful size (Cluster 1: n = 142 (35%); Cluster 2: n = 98 (25%); Cluster 3: n = 160 (40%)). The clusters differed substantially in their attitudinal, normative, control-related, and environmental profiles, suggesting heterogeneous patterns of acceptance toward blockchain-certified sustainable coffee. Taking also the socio-demographic differences and WtP into account, the profile of each of the clusters became even more distinguished. Occupation will not be mentioned in the cluster description, as full-time employment was the dominating form of occupation in all three clusters and did not allow for differentiation.

Cluster 1: "The conscious champions—Engaged and politically trusting proponents" (Illustrative label): Cluster 1 shows strongly above-average scores across nearly all constructs. Trust, Attitude, SN, PBC (PBC 1 and PBC2), and environmental constructs (Env1 and Env3) are particularly high. Political trust is also notably positive. Only Env2 is slightly lower but still positive. Cluster 1 is predominantly female, aged 30–39, living in a partnership without children in a shared household. This segment combines high normative, attitudinal, and control-related openness toward blockchain-certified coffee with a demographic profile often associated with sustainability-oriented purchasing. The majority of this cluster further stated that they would prefer blockchain-certified coffee over other alternatives if it were available and has the highest average WtP of EUR 18.41 for a 500 g pack of blockchain-certified coffee, which is a plus of EUR 6.92 compared to the Fairtrade reference given in the study (500 g for EUR 11.49). This translates into a price premium of 60%. This figure should be interpreted with considerable caution, as a stated preference elicited for a hypothetical product that most respondents had never encountered in market settings, the 60% premium is likely subject to hypothetical bias and may substantially overestimate actual purchase behavior [26]. The predominance of women and middle-aged consumers indicates a group that is economically well settled, value-driven, and committed to purchasing sustainably.

Cluster 2: "The cautious critics—Skeptical and low-involvement rejecters" (Illustrative label): Cluster 2 consistently shows well below-average scores on all constructs. Attitude, Trust, SN, both PBC dimensions, all environmental constructs (Env1–Env3), and political trust are particularly low. This cluster is predominantly male, in the middle-aged segment (40–49 years), and living in a single household. Most participants in this cluster stated that they would buy blockchain-certified coffee only if other purchase criteria were met, too. They also have the lowest average WtP for blockchain-certified coffee at 13.37, which is a plus of EUR 1.88 per 500 g of blockchain-certified coffee and translates into a price premium of 16%. This segment is characterized by general rejection or indifference toward blockchain-certified coffee. The combination of older age, lower consumption, and low psychological scores points to a low-involvement segment that is neither emotionally nor normatively engaged.

Cluster 3: "The balanced pragmatists—rational and moderately open consumers" (Illustrative label): Cluster 3 is close to the mean across most constructs. Scores for Attitude, Trust, SN, and PBC are slightly negative to neutral, while Env2 is slightly positive. Overall, this profile reflects a considered, non-ideologically driven attitude. This cluster is predominantly of male gender, in the oldest age segment across clusters (60–69 years), and living in a shared household with a partner but without children under the same roof. Most participants in this cluster stated that they would buy blockchain-certified coffee only if other purchase criteria were met, too. They have a slightly higher WtP on average compared to Cluster 2 of EUR 13.71, which indicates a premium of plus EUR 2.22, or a price premium of 19%, for 500 g of blockchain-certified coffee. This segment represents a pragmatic majority, neither strongly rejecting nor strongly supporting blockchain-certified coffee. The combination of higher age and moderate psychological scores suggests a group whose intention is strongly influenced by practical benefits, feasibility, and trust.

Viewed in conjunction with the SEM results, the cluster profiles provide a segmentation-level validation of the structural findings. Cluster 1 is characterized by high PBC, SN, and environmental concern scores, which corresponds directly to the consumer profile for whom the SEM-identified predictors of WtP (PBC2 and SN) are maximally activated, explaining this group's highest WtP of EUR 18.41. Cluster 2, with uniformly low construct scores, represents consumers for whom none of the SEM predictors are sufficiently engaged, consistent with their near-floor WtP of EUR 13.37. Cluster 3's moderate PBC and neutral SN scores align with the SEM finding that WtP is sensitive to social norm thresholds, without strong normative activation, economic commitment remains limited despite moderate environmental awareness. Together, the SEM and cluster results are mutually reinforcing: the structural model identifies the mechanisms, while the cluster analysis illustrates how these mechanisms manifest across distinct consumer profiles.

5. Discussion

The following section discusses the findings and insights of this study and implications for industry stakeholders, and its contributions to the body of research on sustainable coffee consumption. Further, its limitations and suggestions for future research are addressed.

5.1. Insights from SEM

In summary, the results show that WtP can be primarily explained through social norms and PBC, as shown in both the traditional and the extended TPB model. Intention can be explained by PBC when only the traditional TPB elements are considered, but environmental beliefs emerge as even more important predictors of intention, when introduced to the model. Whilst respondents may hold favorable attitudes toward blockchain-certified coffee, other factors such as a lack of knowledge, availability, opportunity, or confidence to act on these attitudes may cause this "attitude-intention gap". It further shows that PBC, which can also be considered as actionability, is more relevant than other factors. This finding is consistent with Yi et al. [25], who identified PBC as a significant predictor of purchase intentions for certified aquaculture products, and with Kamalanon et al. [20], who found perceived control to be central in green product adoption. In contrast, Dionysis et al. [21], working in a similar blockchain coffee context, reported a stronger role for attitudes and habits, which may reflect differences in sample characteristics or the maturity of blockchain awareness in the British versus German market.

The stronger role of subjective norm relative to Attitude in predicting WtP deserves particular interpretation. Blockchain-certified coffee is not yet a mainstream product category in Germany, meaning that consumers do not have established habits or strong prior attitudes toward it. In the absence of habitual attitudes, social reference points, i.e., what peers, family, or respected others do or expect, become the dominant decision cue, especially for economically consequential choices such as paying a price premium. This is consistent with Cialdini's social proof principle and with TPB theory, which predicts that SN gains predictive power precisely when personal attitudes are weak or ambiguous [17,68]. It also aligns with findings by Liu et al. [31], who similarly found stronger normative than attitudinal effects in an emerging sustainable product category. SN serves as the differentiator between intention and economic commitment, i.e., WtP, in both the traditional and extended models. This can be explained by the role of SN in social settings in general. However, it can also contribute to the so-called "attitude-behavior gap" [69]. The divergence between intention and WtP as outcome variables is arguably the most theoretically productive finding of this study. It empirically demonstrates the attitude-behavior gap [69] at the level of measurement: environmental beliefs activate moral approval (intention) but do not translate into economic commitment (WtP), while social norms and perceived control are required to bridge the gap. This maps cleanly onto the dual-process framing in behavioral economics, where affective evaluation ("I would like to buy this") is decoupled from incentive-compatible action ("I will actually pay more"). Future research could productively use this intention-WtP divergence as an analytical design feature, rather than treating the two as interchangeable proxies for behavioral propensity.

Whilst intention is unobservable to outside observers, socially observable actions, such as purchasing blockchain-certified sustainable coffee, follow socially established norms (desirable actions). As blockchain-certified sustainable coffee remains a novel, non-standard product, social expectations regarding it may not yet be sufficiently established to influence individual purchase intentions. Thus, the question of whether respondents could realistically imagine the action ("buying blockchain-certified coffee") is most relevant to developing intention.

The results appear consistent against the backdrop of the current literature with some limitations. In line with previous results from [21], [14], and [31], environmental attitudes have been found to be relevant for consumers' purchase intentions. It aligns with the findings from [22] that showed that blockchain helps in signaling sustainability cues to consumers and embedding ecological practices into coffee supply chains [14]. Attitudes, also referred to as habits, have consistently been identified as not significant [21]. The stated WtP corresponds to ranges of 15% at the lowest [29] and 55% at the highest [28] mentioned in the literature, with Cluster 1 stating even higher openness to a price premium of 60%. It bears repeating that this premium was elicited under hypothetical conditions; real market behavior would likely produce considerably lower figures. Overall, the results align well with the existing literature in the domain and offer nuanced insights for the German market. Consumers have distinct perceptions and consequential intentions regarding WtP between traditionally certified sustainable coffee and such with blockchain-enabled sustainability certification. However, several findings deviate from or extend prior work in noteworthy ways. First, the non-significance of Trust, despite its strong theoretical prominence in the blockchain adoption literature [18,33], is a substantive finding. It suggests that in the context of sustainability certification, trust may operate as a necessary background condition rather than a direct behavioral driver, a distinction not drawn in prior studies. This opens a new research direction to explore under what conditions trust translates into direct behavioral effects rather than remains latent. Second, the finding that environmental concern predicts intention but not WtP contrasts with studies such as Kamalanon et al. [20], who found environmental concern to be predictive of both. This divergence may reflect the specific trade-off German consumers make between ecological motivation and economic constraint and warrants cross-cultural investigation. Third, the 60% price premium willingness of Cluster 1 substantially exceeds the upper range of prior studies (55%, [28]), suggesting that a highly engaged segment may be willing to pay considerably more for blockchain-certified coffee than the literature has previously documented.

5.2. Insights from the Cluster Analysis

The three clusters demonstrate that consumer intention toward blockchain-certified coffee is embedded in distinct psychological and sociodemographic constellations. For marketers and industry specialists, this entails important strategic insights to address those customer segments and cater to their specific needs to retain or convert them, depending on the starting point. Highly engaged, predominantly female consumers with strong trust and normative orientations form a clear *pro-adoption segment* (Cluster 1). This group represents the core target audience for blockchain-certified coffee and can be considered "natural believers" who are likely to be forgiving on other product parameters for the sake of buying a sustainable, innovative product linked to technological innovation (blockchain). They are likely to have high purchase intention and high willingness to pay a premium. Given that SN and PBC are the primary WtP drivers (SEM), communication for this segment should leverage peer endorsement (activating SN) and provide clear purchase pathways such as prominently labeled shelf placement or QR-code traceability tools (activating PBC). Marketing strategies can focus on sustainability credentials, transparency, and trust-building messages, as these resonate strongly with their values. It is important to closely monitor this target group and conduct continuous research to understand the evolving (salient) needs of this key group. Traditional measures such as A/B testing in communication and advertisement, social listening, and store or panel data analyses constitute a powerful approach. Further research could explore specific demands on communication channels, price sensitivity, and other preferences of this target group.

The *cautious and critical consumers* (Cluster 2) show pronounced resistance. Acceptance of blockchain-certified coffee is very low in this group and is likely never to be converted into pro-consumers. Standard marketing or educational campaigns are unlikely to be effective. Since neither SN nor PBC are sufficiently activated in this group, short-term sales interventions are unlikely to be effective. Long-term exposure through trusted social networks and regulatory endorsement may gradually build the required normative foundation. Efforts to reach this cluster should focus on long-term trust-building through peers in other consumption categories as well as network, social proof, or regulatory endorsement, rather than immediate sales initiatives.

The third, *pragmatic segment* (Cluster 3) occupies an intermediate position, suggesting that intention formation is contingent upon context-specific cues rather than stable attitudes alone. Strategically, this is the most important developmental group, as their behavior can be shaped. Further, this group expressed the need for a clear value proposition that goes beyond mere sustainability aspects. For them, the product would likely have to perform at least equally well on parameters like taste, ease of use, and price, to be taken into the choice set at the point of purchase. However, this group still holds a smaller, but important WtP a premium for blockchain-certified sustainable coffee, which makes it attractive and can be built on. For the pragmatic segment, PBC is the primary lever: reducing friction at the point of purchase (e.g., simplified blockchain label design, trial pricing) directly targets the control-related barrier identified by the SEM. Marketers should emphasize transparent communication, educational campaigns, and a clearly carved-out value proposition to convert interest into action. Further, deeper insights into corresponding or complementary fields of interest, where this consumer group is naturally inclined and in strong favor of (comparable to members of cluster 1 in this study) might offer valuable strategic insights to transfer to the case of blockchain-enabled sustainability certification in multiple areas. Incentives such as trial offers, visible endorsements, or social influence may be effective.

5.3. Evaluation of Hypotheses

Based on the results, the hypotheses postulated in Section 2 can be evaluated as follows:

H1: Gender was found not to significantly predict attitudes, SN, PBC, or intention. Any effects of gender are mediated through PBC and are therefore indirect and minor. It should be noted that the indirect mediation pathway through PBC was not pre-specified as a hypothesis and represents a post hoc observation. It is reported here as an exploratory finding that warrants confirmatory investigation in future research. However, the cluster analysis showed distinct psychographic profiles for different genders, indicating that their needs and motivations are indeed different and should be addressed accordingly.

H2: H2 is partially supported. Environmental concern positively influences behavioral intention, but does not significantly affect WtP. The hypothesis, as stated, predicted effects on both outcomes and must therefore be considered only partially confirmed. This divergence suggests that environmental motivation translates into moral approval (intention) but is insufficient to overcome the economic barrier of paying a premium.

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H3: Trust in technology or blockchain does not have a significant effect on intention or WtP. This finding indicates that the technology as such, here blockchain, is not the key driver of intention or WtP, but can be regarded as a background facilitator. Thus, communication should focus on benefits rather than detailed information about the technology.

H4: PBC significantly predicts WtP and intention in a traditional TPB model. In the extended model, H5 is supported only for WtP. In line with the TPB, these findings suggest that WtP is resource-dependent. A consumer feeling empowered and capable of acting is willing to pay a premium for it, whereas the intention to act is driven by beliefs.

H5: SN significantly predicts WtP but not intention. Thus, the hypothesis is partially confirmed, with an effect opposite to initial expectations regarding intention. The findings illustrate that SN need to be differentiated, in settings where a decision must be taken (WtP) in contrast to stating an intention. As WtP is objectively measurable in social settings rather than intentions, SN can have a stronger impact here.

H6: WtP is significantly influenced by social norms and perceived control, suggesting that a price premium is feasible. WtP is consistently positive but differs across consumer groups, as shown in the cluster analysis. Tailored price and communication strategies are required to target different consumer subgroups.

5.4. Implications for Coffee Industry and Researchers

From a managerial perspective, the results imply that blockchain-based sustainability certification alone is unlikely to justify a price premium unless it is embedded within strong social norms and perceived consumer agency. Marketing strategies should therefore focus less on technological sophistication and more on social endorsement, peer legitimacy, and transparency regarding consumer impact.

For the coffee industry, this suggests a differentiated communication strategy. Highly engaged consumers represent a natural early adopter group, while the large pragmatic segment can be activated through clear benefit communication, social proof, and price framing. In contrast, skeptical consumers appear largely resistant to informational interventions, indicating limited return on investment in persuasion-based approaches for this group.

5.5. Contributions of the Study

Our study contributes to narrowing the research gap identified in previous literature on blockchain-enabled sustainability certification in coffee. The findings enhance understanding of consumer behavior by showing that while favorable attitudes exist, purchase intention is primarily constrained by PBC, and WtP depends on social norms and PBC. This clarifies how blockchain transparency interacts with consumer perceptions and trust, highlighting which factors drive economic commitment versus mere intention. Overall, the study helps to disentangle the psychological and social drivers of consumer intention and WtP for blockchain-certified coffee. It demonstrates that blockchain technology adds value primarily by enhancing transparency and credibility, but its adoption depends on consumers' perceived ability to act and social normative cues. To promote the purchase of blockchain-certified coffee, companies and stakeholders should design their activities accordingly. This means not only addressing attitudes positively, but also empowering consumers and educating and enhancing their capacity to (inter)act with blockchain and blockchain-certified products in ways that support their individual lived experience and perceptions of social norms. An important meta-finding of this study is that blockchain-specific variables (trust in the technology and in blockchain-enabled certification) do not constitute independent behavioral drivers beyond generic TPB mechanisms. This null result contributes to the literature by suggesting that, from a consumer behavioral perspective, blockchain-certified coffee behaves similarly to other novel sustainability-certified products and adoption is governed by perceived control and social norms, not by blockchain's technological characteristics per se. This finding has implications for how blockchain adoption is framed in future consumer research. Rather than treating blockchain as a unique behavioral stimulus, researchers should examine the conditions under which its specific attributes (immutability, traceability) become salient enough to differentiate it from traditional certification in consumer decision-making.

5.6. Theoretical Implications

From a theoretical standpoint, this study makes three contributions to the TPB literature. First, the non-significance of Trust as a direct predictor, despite strong construct correlations, suggests the need to refine current extensions of the TPB in technology contexts. Trust may function as a moderator or as a background belief rather than as a direct antecedent of intention or WtP. This challenges models that include trust as an additive predictor and calls for its reconceptualization as a boundary condition. Second, the divergent predictive patterns for intention versus WtP demonstrate that these two outcomes, often treated interchangeably in TPB research, are driven by distinct psychological mechanisms. Environmental beliefs drive moral approval (intention), while social and control mechanisms drive economic commitment (WtP). This distinction refines the TPB's application in dual-outcome sustainability research. Third, the cluster analysis contributes theoretically by revealing that the TPB's predictive constructs do not operate uniformly across consumer populations. Different segments are differentially activated by SN versus PBC, suggesting that the TPB's aggregate-level coefficients mask important heterogeneity. The segmentation approach thereby extends the TPB's explanatory power from a population-level model to a profile-level framework, offering a methodological template for future studies.

5.7. Limitations and Future Research

Methodologically, this study demonstrates the value of estimating parallel structural equation models with different dependent variables to disentangle moral approval from economic commitment. While all models exhibit comparable and acceptable fit given their strict theory-driven specification, the systematic differences in path structures underscore the importance of outcome selection in sustainability research.

In addition, the combination of SEM and cluster analysis allows for a richer interpretation of heterogeneity in consumer decision-making. The cluster results reveal three distinct consumer segments ranging from highly engaged sustainability advocates to skeptical rejecters and a promising pragmatic middle group. These segments differ not only in psychological constructs but also in socio-demographic tendencies, reinforcing the importance of segmentation approaches alongside structural modeling.

The robustness of the SEM results was further confirmed through bootstrap resampling, increasing confidence in the stability of the estimated effects despite conservative model fit indices. To address this concern, we conducted three complementary robustness analyses (see Section 4.3). A PLS-SEM re-estimation with more than 2000 bootstrap samples reproduced the substantive pattern. A drop-and-re-estimate procedure confirmed that the structural conclusions hold under sequential exclusion of the AVE $<$ MSV constructs (Trust, PBC2, Env1), and a common latent factor analysis indicated that common method bias accounts for, on average, 4.8 % of the indicator variance, well below conventional concern thresholds. The common latent factor analysis additionally revealed a pattern of elevated method-variance shares concentrated within the Env2 sub-scale, with consistent negative method-factor loadings for Environment_0202–Environment_0205. This is unlikely to represent a classical common-methods artifact or a negative-keying effect:

five of the seven reverse-coded items were already dropped during CFA optimization, and of the two retained, only one (Environment_0205) is among the items with elevated method-variance share. The pattern is more parsimoniously interpreted as residual heterogeneity within Env2, consistent with its comparatively low AVE = 0.593 (cf. Table 4), and is acknowledged here as an Env2-specific measurement limitation that future revisions of the instrument should address. Further limitations should be acknowledged: First, actual purchasing behavior was not observed, which limits the ability to directly test intention–behavior consistency. Second, WtP was measured using a self-reported stated preference format, which may overestimate actual market behavior due to hypothetical bias. Established alternatives for quantitatively eliciting WtP, such as conjoint analysis, Becker–DeGroot–Marschak (BDM) mechanisms, or discrete choice experiments [26], would provide incentive-compatible estimates that more closely reflect real economic behavior and should be considered in future research. Third, although model fit indices fall slightly below conventional cut-off values, the models were deliberately specified without post hoc modifications, prioritizing theoretical consistency over statistical optimization, which represents a genuine limitation. Readers should interpret path coefficients with appropriate caution. Fourth, the study focused on Germany, as one of the key coffee markets globally. Further, the sample was not fully representative of the German population. Thus, results might not be fully transferable. Fifth, as with all survey-based studies on sustainability and ethical consumption, social desirability bias may inflate the reported levels of environmental concern, trust, and willingness to pay. Respondents may have provided answers they perceived as socially acceptable rather than reflecting actual purchase behavior. Future studies could employ unobtrusive measures or experimental designs to mitigate this bias. A further limitation concerns the alignment between the manuscript's blockchain-centred framing and the structural results, which are driven primarily by conventional TPB constructs. We deliberately retained the original framing in this revision because reframing the manuscript a posteriori as a TPB-only study with blockchain as merely an empirical context would entail a non-trivial risk of result-driven framing (positivity bias). We instead emphasise that the null finding for blockchain-specific trust is itself a substantive contribution to the TPB-extension literature: at the consumer level, blockchain-enabled certification appears to be processed through generic TPB mechanisms rather than dedicated technology-trust constructs.

Future research should incorporate experimental or longitudinal designs, include revealed-price mechanisms, and explore cross-cultural differences in the acceptance of blockchain-based certification. Integrating dynamic price experiments could further clarify how social norms and perceived control translate into real purchasing decisions.

6. Conclusions

This study was the first to investigate German consumers' acceptance of blockchain-enabled sustainability certification in the coffee market by combining an extended TPB framework with SEM and cluster analysis. By contrasting behavioral intention and WtP as outcome variables, the analysis provides a nuanced understanding of how moral approval, social mechanisms, and perceived control translate into economic commitment. Existing research focused on conceptual assessments of blockchain's potential in agri-food supply chains, including coffee, yet lacked a broad and in-depth understanding of consumer behavior. The findings contribute to the body of research around sustainable coffee and consumer behavior in several ways. Firstly, the results confirm that behavioral intention and WtP are conceptually distinct outcomes driven by distinct psychological mechanisms. While intention to choose blockchain-certified coffee is primarily influenced by environmental concerns, actual WtP a price premium depends more strongly on subjective social norms and PBC. These nuances are important to understand from an industry stance, considering the common challenges around the so-called "attitude–behavior gap" (here: "attitude–intention gap").

Secondly, the extended TPB model shows that trust, in both technology in general and blockchain technology as such, and in sustainability certification, does not directly affect intention or WtP, despite its strong correlations with other latent constructs. This suggests that trust operates primarily as a background belief that shapes attitudes and perceived control, rather than as a direct behavioral driver. The findings therefore challenge the assumption that, to increase consumer adoption of blockchain-based certification systems, the focus should be on other drivers than technological trust alone.

Thirdly, political orientation strongly shapes attitudes, norms, and PBC but remains fully mediated by TPB constructs, providing further empirical support for the theoretical robustness of the TPB framework when extended by contextual belief systems.

In sum, the study shows that the economic viability of blockchain-enabled sustainability certification is not rejected by consumers per se, but it depends on social and behavioral mechanisms rather than trust alone. The cluster analysis revealed that in order to convert the majority of consumers who are currently undecided (Cluster 3), a clear value proposition beyond mere blockchain-certification in coffee is required, meaning that the product value concept must be designed holistically to meet consumer needs. Blockchain can then act as an enabler to make such quality cues more trustworthy and transparent. These findings highlight the need to align technological innovation with social legitimacy and consumer agency and provide multiple starting points for future research to build on, to unlock the full potential of blockchain in sustainable coffee markets.

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Institutional Review Board Statement: The online survey was conducted in compliance with the German General Data Protection Regulation. Informed consent was obtained from all participants, and data were collected and processed anonymously. Participants had to be above 18 years of age, and participation was voluntary. The participation could be stopped at any point in time, without negative effects on the participants. Participation was incentivized via the professional survey administrator's point-based reward system. The Ethics Committee of the University of Hohenheim confirmed no ethical concerns regarding the study (Reference 2026/12).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are openly available in Zenodo at https://doi.org/10.5281/zenodo.18394576, reference number [38], and will be made publicly available upon acceptance of the paper.

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Appendix A. Univariate Statistics for All Items

Table A1. Univariate statistics for all items, including skewness, kurtosis, and KMO per item.

Item	Skewness	Kurtosis	KMO per Item
Attitude_01	−0.488	−0.127	0.976
Attitude_02	−0.434	−0.251	0.981
Attitude_03	−0.571	−0.100	0.974
Attitude_04	−0.345	−0.426	0.974
Attitude_05	0.505	−0.021	0.977
Attitude_06	−0.522	−0.305	0.988
Attitude_07	−0.548	−0.497	0.979
Attitude_08	−0.453	−0.571	0.978
Trust_0112	−0.588	0.188	0.971
Trust_0113	−0.594	0.447	0.967
Trust_0114	−0.526	0.138	0.984
Trust_0201	−0.401	−0.045	0.963
Trust_0202	−0.358	−0.248	0.960
Trust_0203	0.314	−0.639	0.732
Trust_0302	−0.423	0.410	0.978
Trust_0303	−0.311	0.149	0.964
Trust_0304	−0.368	0.463	0.974
Politic_0101	−0.256	−0.764	0.901
Politic_0102	−0.343	−0.734	0.946
Politic_0103	−0.528	−0.277	0.931
Politic_0104	−0.038	−0.569	0.787
Politic_0105	−0.127	−0.312	0.841
Politic_0106	0.474	−0.535	0.882
Politic_0201	−0.710	0.514	0.966
Politic_0202	−0.037	−0.681	0.779
Politic_0203	0.246	−0.711	0.762
Politic_0204	−0.927	−0.169	0.782
Subjnorm_0101	−0.393	−0.593	0.966
Subjnorm_0102	−0.361	−0.471	0.968
Subjnorm_0103	−0.113	−0.749	0.962
Subjnorm_0104	−0.284	−0.805	0.971
Subjnorm_0105	−0.798	0.125	0.984
Behcontrol_0101	−0.764	0.528	0.967
Behcontrol_0102	−0.879	0.786	0.960
Behcontrol_0103	−0.806	0.749	0.951
Behcontrol_0203	−0.807	0.885	0.877
Behcontrol_0204	−0.650	0.276	0.981
Behcontrol_0205	−0.409	−0.267	0.981
Behcontrol_0206	−0.445	−0.252	0.980
Behcontrol_0207	−0.474	0.045	0.980
Behcontrol_0208	−0.540	0.048	0.981
Behcontrol_0209	−0.543	0.014	0.974
Behcontrol_0210	−0.726	0.453	0.964
Environment_0101	−0.353	0.003	0.985
Environment_0102	−0.464	0.065	0.868
Environment_0103	−0.545	0.323	0.921
Environment_0104	−0.539	−0.008	0.936
Environment_0201	−0.085	−0.976	0.929
Environment_0202	−1.289	1.440	0.837
Environment_0203	−1.081	0.892	0.960
Environment_0204	−1.301	1.462	0.964
Environment_0205	−0.729	−0.693	0.985
Environment_0301	−0.924	0.382	0.868
Environment_0302	−0.761	0.086	0.921
Environment_0303	−0.724	0.390	0.936
Environment_0304	−0.543	0.009	0.929
Environment_0305	−0.469	−0.906	0.837

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Appendix B. Factorability Results for All Constructs

Table A2. Factorability results for all constructs, incl. number of items, Bartlett's test *p*-value, and KMO.

Construct	No. of Items	Bartlett's *p*	KMO
Attitude	8	0.000	0.956
Trust	9	0.000	0.910
Politics	10	0.000	0.754
Subjnorm	5	0.000	0.865
PBC1	3	0.000	0.738
PBC2	8	0.000	0.911
Env1	4	0.000	0.842
Env2	5	0.000	0.733
Env3	5	0.000	0.822

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