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Blockchain Traceability and Consumer Willingness-to-Pay (WTP): Behind the Construction of Transparency Index (TRPI)

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ABSTRACT

This paper examines how consumers perceive and value blockchain-based traceability when food products are associated with health, quality, and sustainability claims. In markets where added value is increasingly communicated through transparency, safety, and authenticity cues, blockchain can act as a supporting tool rather than as a standalone innovation. Survey evidence shows that consumers clearly distinguish between search, experience, and credence attributes, and that willingness to pay for digitally certified products is mainly driven by credence-related concerns such as food safety, fraud prevention, transparency, and sustainability. To capture these attitudes, a Transparency Index (TRPI) is developed by combining perceptions of authenticity, ethical and environmental motivations, and trust in digital certification systems. Consumers who place greater importance on these aspects display a higher acceptance of blockchain-verified products, while standard socio-demographic characteristics explain only a limited share of variation in willingness to pay. The results indicate that blockchain mainly reinforces existing consumer expectations regarding product credibility rather than creating new demand. This is particularly relevant for value-added food markets such as functional, clean-label, allergen-free, and sustainability-oriented products, where trust in production processes and information reliability is essential. The findings suggest that blockchain-based traceability is most effective when combined with established certification schemes, as it strengthens transparency and credibility along the supply chain. By improving access to information on production practices and

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environmental performance, blockchain can also support consumer valuation of carbon-related attributes, making CO_2 reduction efforts more credible and economically relevant in agri-food markets.

Keywords: Blockchain Traceability; Transparency; Consumer Behavior; Willingness-to-Pay; Functional Foods; Sustainable Food Markets; Digital Trust; Credence Attributes

1. Introduction

The agri-food sector is going through a crucial digital transition driven by technological innovations and growing customer demand for transparency, authenticity, and sustainability. In this context, blockchain could be a digital tool to enhance traceability and trust along food supply chains [1, 2]. Blockchain offers a decentralized and tamper-proof ledger of transactions, enabling the documentation and verification of each stage of the production process from farm to consumer. This minimizes information asymmetries between producers and consumers and mitigates enduring issues related to fraud, mislabeling, and quality transparency [3]. Search attributes can be assessed before acquisition (price or appearance), experience attributes are judged post-consumption (taste), and credence attributes (food safety, authenticity, sustainability, and fraud prevention) remain unverifiable even after consumption. Therefore, consumers must depend on indicators and certification systems to evaluate product quality. Blockchain-based traceability could be relevant in this context as it seeks to improve the credibility and verifiability of credence qualities throughout the agri-food supply chain.

Despite strong institutional and industrial interest in blockchain traceability, consumer acceptance remains limited and heterogeneous [4, 5]. While policymakers and firms tend to emphasize the technical robustness and efficiency of blockchain, consumer responses are shaped by cognitive, psychological, and ethical factors. In many mature food systems, such as European contexts, existing certification schemes such as Protected Designation of Origin (PDO), Protected Geographical Indication (PGI), and organic labels already signal origin and quality [6]. In such settings, blockchain does not enter a neutral space, but rather overlaps with and potentially reinforces pre-existing trust structures.

Against this general background, Italy represents a particularly interesting case, given the strong cultural emphasis on origin, authenticity, and food safety [7]. Here, blockchain-based traceability can be interpreted not only as a technological innovation but also as an additional cultural and symbolic layer that interacts with established quality cues. Yet empirical evidence on how consumers in mature food economies perceive and value blockchain certification remains scarce [5]. For this reason, the Italian context is used in this study as an empirical setting to investigate more general mechanisms linking transparency-oriented attitudes and willingness to pay for blockchain-based traceability in mature food markets.

Previous studies have shown that education, digital literacy, and ethical awareness are important drivers of WTP for traceable and sustainable goods, as they increase perceived usefulness and comprehensibility of new technologies [8]. However, these factors are seldom integrated within a single empirical model that also includes trust, perceived transparency, and motivational drivers related to authenticity, safety, and sustainability. Building on work on traceability, technology acceptance, and ethical consumption, including the Technology Acceptance Model [9, 10], this study combines a stated-preference survey with econometric models to link WTP for blockchain-verified products with attitudes towards trust, transparency, and sustainability [11].

It is worth noting that the survey does not refer to a specific functional or reformulated product. Rather, it addresses consumers' evaluation of blockchain-based traceability in food products characterized by added value, where attributes related to health, sustainability, origin, and production processes are particularly salient. Functional and clean-label foods are therefore discussed as relevant subsegments within this broader category, rather than as the exclusive focus of the empirical analysis.

By jointly modelling attitudinal constructs and individual characteristics such as education, income, and age, the paper offers an integrated view of the determinants of WTP that has rarely been provided in prior research. In doing so, it contributes empirical evidence from a mature Mediterranean food market and sheds light on whether blockchain certification can effectively complement traditional quality schemes and under which consumer conditions it translates into a measurable price premium [12, 13].

Within this perspective, the analysis adopts a broad view of value-added food products, allowing the empirical framework to capture transparency-oriented attitudes that cut across different product categories, including but not limited to functional and clean-label foods. Against this background, the aim of this paper is to identify the relative contribution of transparency-oriented attitudes, ethical and sustainability motivations, and socio-demographic and economic factors to WTP, through the construction and testing of a composite Transparency Index (TRPI).

The paper is organized as follows. Section 2 reviews the literature related to blockchain and the themes correlated. Section 3 shows data and methodology. Section 4 presents empirical results. Finally, conclusions and some policy implications are also included in the last section of this work.

2. Literature Review

This section reviews the main theoretical and empirical contributions underpinning the study, focusing on five interconnected dimensions:

(1) the technological foundations of blockchain in food traceability,
(2) the role of consumer trust,
(3) willingness to pay (WTP) for traceability attributes, and
(4) the influence of education, income, digital literacy, and ethical awareness on blockchain acceptance,
(5) functional food and clean-label products.

The increasing complexity and globalization of agri-food supply chains have intensified the demand for transparency and reliability of information. Blockchain technology is recognized as a catalyst for traceability, facilitating decentralized, immutable, and verifiable data exchange among various stakeholders [14, 15]. Technologically, Ellahi et al. [16] demonstrate the potential of distributed ledgers and smart contracts to meet traceability needs in the food sector, concurrently guaranteeing nonrepudiation and protection against data manipulation. Furthermore, Lateb et al. [17] present a comprehensive review of blockchain applications in food supply chains, highlighting its ability to improve transparency, auditability, and data integrity within networks involving multiple actors.

A bibliometric analysis of blockchain applications within food and halal supply chains has been undertaken, emphasizing traceability, visibility, and authenticity as fundamental technological advantages of blockchain-based systems [18]. Unlike conventional databases, blockchain technology records each transaction within an immutable ledger, thereby diminishing the potential for fraud and lessening information asymmetry, especially in markets where credence attributes like geographical origin, organic certification, and sustainability are crucial [19]. Empirical research indicates that blockchain can improve perceived authenticity, food safety, and trust within supply chains [20].

The existing research indicates that consumers' valuation of blockchain-based traceability is primarily shaped by the perceptions it fosters regarding trust, safety, authenticity, and transparency, rather than the underlying technology. These recurring elements, which form the conceptual foundation of the Transparency Index (TRPI) employed in this study, are consistently highlighted in the literature.

Trust constitutes a critical determinant of consumer reactions to blockchain-based systems. By introducing a novel layer of technological trust, blockchain reallocates a portion of the credibility typically held by institutional intermediaries, such as certification bodies and brands, to data-driven mechanisms [21]. Furthermore, Wu et al. [22] demonstrate that blockchain-based food traceability systems substantially improve trust in organic food and influence purchase intentions, al-

though technology anxiety mitigates these effects.

At a broader level, Nguyen and Nguyen [23] conceptualize consumer trust in food as multidimensional, encompassing trust in products, actors, and systems, which technological solutions such as blockchain can reinforce only when aligned with institutional and social cues. Focusing on sustainability communication, Reitano et al. [24] develop a "sustainability trust" construct for QR-code and blockchain-backed traceability tools, showing that such systems strengthen trust in product sustainability information and in the information environment itself. However, as Vasileiou et al. [25] argue, trust in blockchain depends not only on transparency but also on perceived ethicality, institutional credibility, and the alignment between technology and consumers' moral expectations. In countries like Italy, where PDO and PGI labels already carry substantial symbolic weight as guarantees of authenticity, blockchain is more likely to complement than replace existing certification schemes [26]. Consumers tend to associate blockchain with enhanced food safety and origin reliability, whereas its link with environmental sustainability is often less immediate and requires explicit communication [27].

Against this background, several empirical studies show that consumers are generally willing to pay a premium for traceability attributes that reduce uncertainty, such as certified origin, organic labelling, or blockchain-based verification [28]. Blockchain acts as a high-quality information signal: by providing verifiable data on production and logistics, it justifies higher prices in the eyes of consumers who value transparency and protection against fraud. Ershadrad [29] employs a discrete choice experiment focused on leafy greens within the United States, demonstrating a positive marginal willingness to pay (WTP) for blockchain-based QR-code traceability, especially among consumers exhibiting heightened food safety apprehensions. Conversely, Kabir et al. [30] discovered that consumers are inclined to pay a premium for blockchain-traceable infant formula, primarily motivated by perceived food safety hazards. Furthermore, Kabir et al. [30] reveal that Bangladeshi consumers display considerable WTP for traceable vegetables when pesticide details and harvest dates are explicitly provided, implying that traceability premiums are not confined to high-income demographics.

Positive WTP for blockchain-labelled foods has been documented in multiple contexts, although the magnitude of the premium varies across products, markets, and consumer segments [31–33]. Other studies suggest that WTP is driven less by income constraints and more by ethical and psychological motivations, reinforcing the need to integrate attitudinal constructs (trust, perceived importance, knowledge) with socio-demographic factors (education, age, income) [34, 35].

Taken together, these findings point to the limits of analyzing willingness to pay through single indicators. They instead support the use of composite measures that can account for the combined influence of trust, ethical motivations, and perceived importance of transparency. The TRPI is designed with this objective in mind, bringing these dimensions together within a single empirical construct.

Recent empirical contributions using discrete choice experiments and random-parameter logit models consistently confirm positive WTP for food products traced with blockchain-based systems. Petrontino et al. [36], for example, show that Greek consumers are willing to pay a price premium for feta cheese labelled with blockchain-based traceability, with effects strongest among ethnocentric consumers and when information is provided through QR codes. Italian consumers, according to Maesano et al. [31], assign higher utility and willingness to pay to pasta products whose origin is verified through blockchain technology, especially when this traceability is coupled with environmental or quality certifications. Furthermore, Jo and Lusk [37], in their study of Chinese online shoppers, reveal that blockchain traceability increases the perceived value and purchase intention for organic foods available on e-commerce platforms.

Education and digital literacy consistently appear as strong predictors of both blockchain acceptance and WTP. In a mini-review of blockchain technologies for sustainable food traceability, Castellini et al. [38] similarly highlight consumer knowledge, perceived benefits, and pro-sustainability attitudes—variables closely linked to education and digital literacy—as key drivers of acceptance. A fifth, cross-cutting dimension relevant to this

study concerns consumers' willingness to pay for functional and clean-label attributes and how these interact with blockchain-based traceability. Research on functional foods shows that consumers are generally willing to pay a premium for products that credibly deliver health benefits (e.g., added fibre, probiotics, omega-3), especially when these benefits are clearly communicated and supported by trustworthy institutions [39]. Meta-analyses consistently show a positive willingness to pay (WTP) for health-related features, with higher premiums when the information is specific, based on scientific evidence, and relevant to current health issues [40]. These studies show that health awareness, risk aversion, and trust in regulatory or certification bodies are the main factors driving WTP, while price sensitivity is less important. This pattern is similar to what we see in blockchain research, where consumers prefer technologies that reduce information gaps about safety and quality, rather than those that are simply new.

The clean-label movement further reinforces this logic. Clean-label products emphasize short and "recognisable" ingredient lists, absence of synthetic additives, and minimal processing. Empirical work shows that many consumers interpret clean labels as a proxy for naturalness, safety, and transparency, and are willing to pay higher prices for such products, particularly in categories like snacks, dairy, and ready meals [37, 41]. However, reviews also highlight considerable ambiguity around what "clean" actually means, with overlaps and confusion between "natural", "organic", "additive-free", and "unprocessed" [42]. As a result, clean-label positioning often depends on heuristic trust in brands and labels rather than on verifiable information about ingredients and processes. This creates an ideal space for blockchain: by recording ingredient sourcing, processing steps, and the absence of specific additives in an immutable ledger, blockchain can turn otherwise vague clean-label claims into auditable, data-driven assurances.

Despite the expanding literature, significant gaps remain. Most analyses still focus on Asian markets or rely on hypothetical experimental settings, leaving European consumer behaviour, particularly within Southern Europe's strong certification culture, insufficiently explored [43–47]. Furthermore, few studies empirically integrate trust, education, perceived importance of transparency, and ethical motivations into a unified framework explaining WTP for blockchain-traced foods. Addressing this gap would enable a more nuanced understanding of how technological, cognitive, and moral factors interact in shaping consumers' valuation of blockchain-enabled traceability. Against this background, the present study proposes an integrated framework centred on the Transparency Index (TRPI), which translates the main insights of the existing literature into an operational measure linking transparency-oriented attitudes and trust in blockchain-based traceability to consumers' willingness to pay.

3. Data Collection and Methodology

The present study addresses these gaps by combining a rich set of attitudinal measures, trust in blockchain, importance of transparency, authenticity, and sustainability perceptions with socio-demographic characteristics and economic variables in a single empirical model. In doing so, it contributes to the broader debate on how digital traceability can support health-driven and "functional" food markets, strengthen consumer trust, and align technological innovation with sustainability and resilience goals in agri-food systems.

The empirical analysis relies on data collected through a structured online questionnaire aimed at capturing consumer awareness, attitudes, perceived benefits and barriers, and willingness to pay for blockchain traceable food products. The survey was conducted between September and October 2025 using Google Forms and distributed through social media, university mailing lists, and online communities focused on food sustainability and digital innovation. This strategy allowed for wide national coverage at relatively low cost and encouraged participation from respondents with diverse socio-demographic backgrounds.

The final sample consists of 1500 valid responses from adult consumers residing in Italy. While the use of a convenience sampling approach may have led to an over-representation of individuals who are more digitally active and familiar with online information tools,

it remains suitable for exploring consumer perceptions and valuation mechanisms related to blockchain-based traceability.

This reflects the recruitment channels used and the focus of the study on attitudes toward digital traceability technology. As a consequence, the findings should not be interpreted as fully representative of the Italian population as a whole, but rather as indicative of behavioural patterns among consumers who are more likely to encounter and engage with blockchain-based traceability in real market settings.

The questionnaire comprises four sections:

(1) socio-demographics;
(2) food purchasing habits;
(3) blockchain awareness, perceived transparency, and motivational drivers;
(4) willingness to pay for blockchain-verified products using a hypothetical choice scenario.

Willingness to pay for blockchain-based traceability was elicited through a hypothetical choice scenario in which respondents were asked whether they would be willing to pay more for a food product whose information was verified through blockchain technology, compared to an otherwise similar product without blockchain-based traceability. The scenario did not specify a precise monetary premium, as the objective was to capture consumers' attitudinal predisposition toward paying a premium for enhanced transparency rather than to estimate a precise willingness-to-pay amount. Accordingly, the dependent variable was modeled as a binary indicator. This approach is consistent with prior studies focusing on transparency and credence attributes, where binary WTP measures are commonly used to assess acceptance of information-enhancing technologies under hypothetical conditions.

The survey explicitly incorporated items capturing consumer orientations toward health, safety, and sustainability dimensions that are highly relevant in functional and reformulated food markets. Motivations related to authenticity, nutritional transparency, risk avoidance (e.g., fraud, contamination), and sustainability were used to construct the Transparency Index (TRPI), making the empirical framework aligned with the needs of health-oriented food systems. To capture consumers' overall attitude toward transparency-enhancing technologies, the analysis employs a Transparency Index (TRPI) constructed as the standardised mean of five conceptual components:

(1) trust in blockchain-based certification,
(2) importance attributed to transparency and traceability,
(3) perceived authenticity of the supply chain,
(4) perceived sustainability of digitally certified products,
(5) perceived reduction of fraud risk.

The TRPI synthesises multidimensional attitudes into a single metric representing consumers' transparency orientation. It displays moderate average levels and substantial heterogeneity, reflecting the coexistence of highly informed, transparency-driven consumers and others less knowledgeable or indifferent.

The choice of the five components is not random but stems from a preliminary analysis based on the PCA (principal component analysis) method on standardized scores for trust in blockchain, importance of transparency/traceability, perceived authenticity, perceived sustainability, and perceived security (reduction of fraud risk). As shown in **Table 1**, the PCA reveals a dominant first component that explains 61.03% of the total variance, with all dimensions showing positive and substantial loadings on the first component.

To identify the determinants of willingness to pay for blockchain-traceable food products, a binary dependent variable $\mathrm{WTP_i}$ was defined as:

$$\mathrm{WTP_i} = \begin{cases} 1 & \text{if the respondent is willing to pay more for blockchain traceability} \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

The core explanatory variable is the Transparency Index (TRPI). Additional covariates include:

- The education level (Edu_i)
- The income category ($Income_i$)

- sustainability motivation (when not embedded in the TRPI robustness checks),
- gender and age group ($Gender_i$ and Age_i)
- frequency of food purchases ($Freq_i$)

Table 1. PCA on TRPI.

Dimension	Principal Component (1) Loading
Trust in blockchain	0.495
Importance of transparency/traceability	0.475
Perceived authenticity	0.417
Perceived sustainability	0.436
Perceived security/fraud-risk reduction	0.405

The baseline econometric model follows a logistic specification:

$$\begin{aligned} \mathrm{P}(\mathrm{WTP_i} = 1) = \mathrm{F}(\beta_0 + \beta_1 \mathrm{TRPI_i} + \beta_2 Edu_i \\ + \beta_3 Income_i + \beta_4 Gender_i + \beta_5 Age_i + \beta_6 Freq_i) \end{aligned} \quad (2)$$

where $\mathrm{F}(\cdot)$ is the logistic cumulative distribution function.

To ensure robustness to distributional assumptions, both Logit and Probit models were estimated. Although the two approaches differ in the assumed distribution of the error term logistic vs. normal the estimated coefficients maintain consistent signs, magnitudes, and statistical significance across specifications. This concordance indicates that the main findings are not sensitive to the functional form and that the TRPI remains a stable and substantive predictor of WTP.

Logit results are reported using odds ratios to enhance interpretability, while Probit marginal effects are used to assess incremental changes in predicted probability.

4. Results

Before presenting the econometric estimates, this section summarizes the main descriptive patterns emerging from the dataset. **Tables 2** and **3** report, respectively, the socio-demographic profile of respondents and the distribution of the attitudinal variables used to construct the Transparency Index (TRPI). Together, these tables provide an overview of the characteristics and perceptions that shape consumer attitudes toward blockchain-enabled traceability.

Table 2. Socio-demographic Characteristics and Summary Statistics.

Variable	Levels	Frequency	%
Gender	Male	686	45.7
	Female	780	52.0
	Other	34	2.3
Age group	18–30	438	29.2
	31–45	612	40.8
	46–60	310	20.7
	60+	140	9.3
Education	Middle school	324	21.6
	High school	635	42.3
	University degree	420	28.0
	Postgraduate	121	8.1
Income level	Low	289	19.3
	Lower-middle	440	29.3
	Middle	396	26.4
	Upper-middle	245	16.3
	High	130	8.7
Purchase frequency	Weekly	510	34.0
	Twice a week	438	29.2

Table 2. *Cont.*

Variable	Levels	Frequency	%
Purchase frequency	Monthly	330	22.0
	Occasional	222	14.8

Table 3. Attitudinal Variables and TRPI Components.

Variables	Mean	Std. Dev.
Trust_Blockchain	2.80	1.25
Trace_Importance	2.80	1.22
Motiv_Safety	3.22	1.10
Motiv_Sustainability	2.77	1.16
Motiv_Autenticity	2.77	1.10
Motiv_Trasparency	2.79	1.14
Barrier_Price	0.23	0.42
Barrier_LowKnowledge	0.31	0.46
Barrier_Indifferency	0.19	0.40
Barrier_LowTrust	0.22	0.42
Benefit_Safety	0.55	0.50
Benefit_Autenticity	0.44	0.50
Benefit_Origin	0.51	0.50
Benefit_Antitrust	0.42	0.49

Table 2 highlights a balanced and heterogeneous sample in terms of gender, age, education, income, and purchasing habits, conditions that ensure sufficient variability for identifying behavioral determinants of willingness to pay. **Table 3** complements this evidence by illustrating moderate but highly dispersed levels of trust in blockchain, perceived importance of traceability, and motivations related to safety, authenticity, transparency, and sustainability, as well as the prevalence of perceived barriers and benefits.

Table 4 reports pairwise correlations between the Transparency Index (TRPI) and the main covariates included in the subsequent econometric models. Correlations are relatively low and fully within acceptable ranges, with TRPI most strongly associated with purchase frequency (0.518), followed by education (0.281). **Table 5** shows the VIF values, all well below the conventional threshold of 5, confirming the absence of harmful multicollinearity.

Table 6 reports the results of the binary choice models estimating the probability that a respondent is willing to pay a price premium for blockchain-traceable food products. Both Logit and Probit estimates indicate that TRPI is by far the strongest predictor of WTP. The magnitude and significance of the TRPI coefficient remain stable across functional forms, confirming that transparency-oriented consumers show systematically higher propensity to pay for digitally certified products.

Table 4. Correlation Matrix (TRPI and Covariates).

Variable	TRPI	Edu Level	Income	Purchase Freq
TRPI	1.000			
EduLevel	0.281	1.000		
Income	0.077	0.412	1.000	
PurchaseFreq	0.518	0.105	0.123	1.000

Table 5. Variance Inflation Factors (VIF).

Variable	VIF
TRPI	1.49
PurchaseFreq	1.40

Table 5. *Cont.*

Variable	VIF
EduLevel	1.32
Income	1.23
AgeGroup	1.00
Gender	1.00
Mean VIF	1.24

Table 6. Logit Model on WTP_yes.

Variable	Coef.	Std. Err.	*p*-Value
Pseudo-R^2 = 0.437			
TRPI	2.346	0.223	0.000
EduLevel	0.160	0.196	0.412
Income	0.726	0.121	0.000
Gender	0.379	0.231	0.101
AgeGroup	−0.052	0.116	0.655
PurchaseFreq	0.679	0.159	0.000
Pseudo-R^2 = 0.466			
TRPI	1.243	0.115	0.000
EduLevel	0.045	0.101	0.657
Income	0.385	0.064	0.000
Gender	0.170	0.125	0.175
AgeGroup	−0.022	0.063	0.730
PurchaseFreq	0.350	0.083	0.000

Income and purchase frequency also exert positive and significant effects, suggesting that economic availability and involvement in food purchasing routines play an additional role. By contrast, education, age, and gender do not exhibit significant associations with WTP, indicating that demographic segmentation is much less relevant than cognitive and ethical drivers.

Marginal effects reported in **Tables 7** and **8** provide a behavioral interpretation of the estimated coefficients. A one-standard-deviation increase in TRPI raises the probability of WTP by approximately 1.9 percentage points. Income and purchase frequency also show positive marginal impacts. Demographic variables remain non-significant, confirming the centrality of transparency-orientations and behavioural engagement over socio-demographic traits.

Table 7. Marginal Effects—Logit.

Variable	dy/dx	Std. Err.	*p*-Value
TRPI	0.0191	0.0046	0.000
EduLevel	0.0013	0.0016	0.412
Income	0.0059	0.0017	0.001
Gender	0.0031	0.0020	0.123
AgeGroup	−0.0004	0.0009	0.657
PurchaseFreq	0.0055	0.0018	0.002

Table 8. Marginal Effects—Probit.

Variable	dy/dx	Std. Err.	*p*-Value
TRPI	0.0190	0.0058	0.001
EduLevel	0.0007	0.0015	0.657
Income	0.0059	0.0021	0.005
Gender	0.0026	0.0021	0.211
AgeGroup	−0.0003	0.0010	0.732
PurchaseFreq	0.0053	0.0020	0.009

Results confirm that transparency-oriented consumers, especially those motivated by safety, sustainability, and authenticity, all key components of functional and responsible food consumption, show the strongest WTP for blockchain certification. This indicates that blockchain is particularly valued in product categories where consumers demand high verification of health-related and sustainability claims.

Although the marginal effects indicate that a one-standard-deviation increase in the TRPI raises the probability of willingness to pay by approximately 1.9 percentage points, this magnitude should be interpreted with caution. Marginal effects in binary choice models represent average changes across the full sample and tend to mask substantial heterogeneity in consumer responses. Moreover, willingness to pay for blockchain-based traceability reflects a threshold-type decision rather than a continuous adjustment: for most consumers, traceability acts as a qualifying attribute that becomes relevant only once a minimum level of trust and transparency orientation is reached, while price sensitivity and reference prices remain dominant drivers of the final choice. From an economic perspective, these results suggest that blockchain-enabled transparency generates a modest average premium in the general population, but may exert a stronger influence within specific consumer segments. It should be acknowledged that willingness to pay is elicited in a hypothetical setting and measured through a binary indicator, which may be affected by hypothetical bias. As documented in the literature on ethical and sustainable consumption, stated intentions do not always translate into actual purchasing behaviour, reflecting a well-known attitude–behaviour gap.

5. Discussions

The findings shed light on how consumers interpret and value blockchain-based traceability in agri-food markets. The Transparency Index (TRPI), composed of capturing trust, perceived importance of traceability, and motivations linked to authenticity, sustainability, and fraud prevention, emerges as the main driver of willingness to pay. This confirms that blockchain operates above all in the cognitive and credence space of food evaluation: consumers who already value transparency are more willing to reward digital certification systems.

The strong predictive power of TRPI suggests that blockchain is not seen as a purely technical upgrade, but as a symbolic guarantee of honesty and integrity along the supply chain. Consumers read blockchain through ethical and safety concerns rather than through technical reasoning, which is in line with recent evidence on the role of moral trust, authenticity, and safety orientation in supporting blockchain acceptance. In this perspective, blockchain does not replace existing schemes (PDO, PGI, organic), but adds an extra layer of verifiability to them.

While the Technology Acceptance Model (TAM) is often used to explain the adoption of new digital technologies, the present study does not employ TAM as a formal modeling framework. Rather, TAM provides a broader interpretative background for understanding general attitudes toward technological solutions. In this study, the empirical focus is deliberately placed on trust, transparency, and the valuation of credence attributes, which are particularly relevant in agri-food markets characterized by information asymmetries. Accordingly, the Transparency Index captures aspects that extend beyond traditional technology acceptance constructs, highlighting the role of trust, ethical considerations, and perceived integrity in shaping consumer willingness to pay. The absence of significant effects for gender, age, and education suggests that acceptance of blockchain-based traceability is not driven by socio-demographic segmentation. Rather, it is influenced by values, attitudes, and risk perceptions, indicating that the potential market for blockchain-traceable products is better defined by psychological and behavioural profiles than by demographic characteristics.

At the same time, economic behaviour matters. While static socio-demographic traits do not affect willingness to pay, income and purchase frequency emerge as relevant drivers, pointing to the importance of economic capacity and habitual involvement in food purchasing in shaping consumers' valuation of blockchain-enabled transparency.

Income and purchase frequency are positively associated with WTP, indicating that economic capacity

and involvement in food purchasing affect how attitudes translate into actual behaviour. In the OLS model, education becomes relevant for the premium level among those willing to pay, consistent with the idea that understanding quality signals and interpreting certifications requires cognitive resources that make higher prices more acceptable.

The findings suggest that blockchain technology offers the most significant value within food categories distinguished by robust credence attributes and health or sustainability assertions, including products boasting high protein content, allergen-free status, organic certification, clean labeling, and reduced risk profiles. Within these specific markets, blockchain functions as a digital trust facilitator, furnishing verifiable data concerning nutritional quality, production methodologies, safety protocols, and environmental impact. Consumers perceive this enhanced traceability as an indicator of product integrity, thereby rendering blockchain especially well-suited to support the advancement of functional and clean-label food segments.

Blockchain technology should be viewed primarily as a means of bolstering the trustworthiness of production processes that support clean label assertions, rather than as a method for validating ingredient composition, a function already governed by existing legal frameworks. While the survey did not focus on specific products, its conclusions are particularly pertinent to market segments characterized by credence attributes concerning safety, authenticity, and sustainability. Consequently, the TRPI framework, though product-agnostic, offers valuable insights, especially for food categories where transparency and consumer trust are critical factors in purchasing decisions.

6. Conclusions

This study contributes to the literature on blockchain traceability in agri-food markets by showing that the value of blockchain lies less in the technology itself and more in how it supports existing transparency-oriented preferences. Evidence from a mature Mediterranean food economy suggests that blockchain does not generate willingness to pay on its own, but strengthens consumers' demand for verifiable authenticity, trust, and supply-chain integrity.

A central contribution of the paper is the construction of the Transparency Index (TRPI), which integrates trust, perceived importance of transparency, sustainability concerns, and fraud prevention into a single measure.

The results indicate that cognitive and ethical orientations matter more than standard socio-demographic characteristics. While age or gender explain little, transparency-related attitudes play a key role, especially in product categories characterised by strong credence attributes such as origin labels, sustainability claims, functional foods, and clean-label products.

Some limitations should be noted. The analysis relies on stated preferences and a binary measure of willingness to pay, and focuses on a single national context. It should be acknowledged that the Transparency Index may partly capture broader psychographic traits such as health consciousness, risk aversion, or ethical sensitivity that are themselves associated with a higher willingness to pay. In this sense, TRPI should be interpreted not only as a direct driver of willingness to pay for blockchain-based traceability, but also as a proxy for a more general "conscientious consumer" orientation. Future research could extend the framework to other countries, use experimental or real-purchase data, and explore how blockchain interacts with branding strategies and regulatory settings.

From a policy perspective, the results suggest that the value of blockchain in agri-food systems lies less in the technology itself and more in how it is framed and used. Consumers respond primarily to simple and verifiable assurances (where a product comes from) how it was produced, and whether its claims can be trusted rather than to technical descriptions of digital infrastructures. Policy and communication efforts should therefore emphasize transparency, integrity, and fraud prevention. Consequently, the substantial influence of the Barrier_LowKnowledge variable suggests that a lack of understanding regarding digital traceability tools may hinder the practical implementation of transparency-focused perspectives. Recent findings concerning technical digital assistants demonstrate that, with advanced technologies, users often value familiarity and perceived

ease of use more than the technology's inherent novelty. This implies that blockchain-based traceability interfaces within food markets should be developed to be familiar, intuitive, and convenient, rather than solely technologically advanced, to effectively address knowledge barriers and foster broad consumer participation.

The weak role of most socio-demographic variables indicates that targeted interventions aimed at specific groups are not strictly necessary. More inclusive strategies based on clear and accessible information tools (understandable labels, informative QR codes, and concrete public communication) appear more effective in conveying the added value of digital traceability.

The results further support a layered governance model, wherein blockchain technology serves to augment, rather than supplant, current certification frameworks. Digital traceability, contingent upon the establishment of interoperability and system-wide coordination, can strengthen quality designations like PDO, PGI, and organic certifications.

Simultaneously, the significance of income levels and purchase frequency underscores the enduring influence of price. Consequently, if products certified via blockchain consistently command premium prices, the accessibility of safer or more sustainable food options could be compromised.

Efforts to diminish the financial burdens of adoption and certification, especially for smaller enterprises, can serve to alleviate this potential disadvantage.

This finding presents an equity issue warranting direct policy consideration. Should the expenses linked to blockchain adoption and certification be entirely transferred to consumers, digitally traceable and safer food products could become a premium offering, primarily available to wealthier households. To circumvent this scenario, public intervention can be instrumental in reducing adoption costs for small and medium-sized producers, potentially through the implementation of targeted subsidies, tax credits for digital certification expenditures, or the establishment of shared public digital infrastructures for traceability.

From a managerial perspective, blockchain should be viewed as a trust-building and communication tool. Investments in traceability are most effective when accompanied by clear narratives on transparency and authenticity, as well as pricing strategies that keep blockchain-certified products within reach of a broad consumer base, especially in functional and clean-label markets. Additionally, the adoption of blockchain as a reliable transparency mechanism necessitates internal organizational transformation. The implementation of blockchain transcends simple communication or labeling; it represents a transition toward data-driven decision-making. This entails that firms develop digital leadership and analytical skills essential for ensuring the accuracy, timeliness, and strategic relevance of on-chain recorded information. Empirical findings from small and medium-sized enterprises (SMEs) indicate that the integration of technological competence with data-driven decision-making and digital leadership is crucial for fostering creativity and maintaining a competitive edge. In the agri-food sector, this suggests that the sustainability of consumer willingness-to-pay premiums for blockchain-certified products revolves around producers' investment in robust data governance and internal decision-making frameworks, rather than relying exclusively on the consumer-facing blockchain label. Finally, blockchain traceability should ultimately be conceptualized as an integrated component within a wider digital innovation and marketing framework, rather than a singular instrument. Recent research in the hospitality and tourism sectors indicates that generative AI strategies and novel approaches can augment employee creativity and marketing outcomes. Similarly, the detailed and verifiable data produced by blockchain technology can function not only as a verification tool but also as a valuable resource for AI-driven storytelling, personalized communication, and interactive digital services within food markets. Consequently, the utilization of blockchain data, in conjunction with generative AI tools, can strengthen the "*digital trust*" ecosystem surrounding food products, enabling companies to collaboratively develop more compelling narratives concerning provenance, sustainability, and quality across various digital platforms. By strengthening the credibility of environmental information along the supply chain, blockchain-based traceability can help translate CO_2 reduction efforts into attributes that consumers recognize,

trust, and are willing to value economically.

Author Contributions

C.S. contributed to methodology, software, validation, data curation, and writing, review, and editing; F.M. contributed to conceptualization, formal analysis, and writing—original draft preparation; F.S. contributed to supervision, resources, writing—original draft preparation, and funding acquisition; All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The data used in this study were collected by the authors. The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

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