Blockchain technology adoption in food label systems. The impact on consumer purchase intentions

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Abstract

Framing of the research. *Food labels have a significant impact on shaping consumers' intentions to purchase food products. The adoption of blockchain technology with regard to food labels holds potential as an effective means of enhancing the data accessible to consumers, thereby shaping their purchasing patterns.*

Purpose of the paper. *This study adopts the Unified Theory of Acceptance and Use of Technology as a theoretical framework to understand how blockchain technology adoption in food label systems might influence consumers' intention toward purchasing labeled food.*

Methodology*. A research model with six hypotheses has been developed and tested on a sample of 825 users. The proposed model also highlights the importance of perceived trust and perceived product transparency on customers' purchase intentions. Data have been analyzed via a PLS-SEM approach.*

Findings*. Results show that the adoption of blockchain technology to protect information throughout the food supply chain can positively influence consumers' purchase intentions.*

Research limits. *This work has some limitations, which could serve as a pathway for future investigations. First, it has been conducted within a single country (Italy). Next, though it meets the required sample size for conducting analysis, future studies could enhance the number of observations to reinforce this study's findings.*

Practical implications. *This research contributes to a deeper understanding of the role of blockchain technology in the food industry by providing empirical evidence of its potential as a valuable tool for sustaining company purchases.*

Originality of the paper. *This study advances scientific knowledge of blockchain technology in the specific context of the food sector.*

Key words: *blockchain technology; food label; behavioral intention*

1. Introduction

In 2022, the worldwide food industry realized a total revenue of US$8,670 billion (Statista, 2023). The food market's global revenue is predicted to see steady growth from 2023 to 2028, with a total increase of 3.6 trillion U.S. dollars, representing a growth rate of 38.46%. This continuous growth is expected to culminate in 2028 when revenue is estimated to reach a new record high of 12.97 trillion U.S. dollars. It is worth noting that the food market has experienced a consistent upward trend in revenue over the past several years (Statista, 2023).

Currently, the industry is grappling with significant pressures and hurdles, including the pervasive influence of e-commerce, the implementation of cutting-edge digital technologies, and the growing attention paid to sustainability practices (Harvard Business Review, 2023). Accordingly, as reported by IBM (2022), more than half of consumers express their willingness to pay a premium for sustainably sourced products. The intertwining of digitalization and sustainability within the food industry heralds a transformative era in which technological advancements are harnessed to amplify sustainable practices (Jansen, 2003; Parmentola *et al.*, 2022). The introduction of digital technologies, such as blockchain technology (BCT), allows businesses to gather and analyze data to promote sustainability in areas that were once a black box (Oguntegbe *et al.*, 2021). Specifically, by harnessing the power of digitalization, the food industry is poised to usher in a new paradigm of responsible and sustainable production, transparent sourcing, and reduced environmental impact. Because customers are becoming more aware of the quality and safety of products in the food sector (World Health Organization, 2019), both academics and practitioners are paying more attention to BCT as a tool for food traceability, safety, and transparency (Feng *et al.*, 2020; Lin *et al.*, 2021). The adoption of BCT extends benefits not solely to customers seeking more comprehensive information about food products but also to companies (Stranieri *et al.*, 2021). Information asymmetry diminishes when customers have insight into the provenance and transit of their purchases, thereby contributing to the mitigation of health hazards (Yoo *et al.*, 2015). This augmented transparency equips consumers with improved capabilities to evaluate the attributes of a specific product, which instills trust and fosters more informed choices (Ghahremani-Nahr *et al.*, 2022). Specifically, recent trends indicate an increased awareness of the source and authenticity of food products. These factors are being noted as pivotal aspects of evaluating and making decisions that influence consumer preferences (Marozzo *et al.*, 2022).

Previous research has provided a preliminary understanding regarding the regulatory aspects of BCT implementation in the food industry (Li *et al.*, 2023; Duan *et al.*, 2020). These studies focused primarily on investigating the potential benefits associated with adopting BCT, such as improving traceability efficiency (Feng *et al.*, 2020) and supply chain transparency (Sunny *et al.*, 2020). However, there are also challenges, including scalability, lack of legislation, and immature technology (Zhao *et al.*, 2019; Lohmer and Lasch, 2020). Moreover, prior research (Rogerson and Parry, 2020) has demonstrated that BCT features play a significant role in establishing information transparency throughout the supply chain, involving different participants. Tokkozhina *et al.* (2023) investigated the implications of information accessibility in the context of adopting BCT pilots within the supply chain. Their findings revealed that BCT's reputation as a trust-building technology does not eliminate the need for trustworthy relationships before adoption due to the human intervention required for information input.

On the other hand, Treiblmaier and Petrozhitskaya (2023), focusing on the consumer side, have studied how BCT-based loyalty programs transform B2C relationships via innovative customer services that maintain important properties of a sharing economy. Nevertheless, only limited research has investigated how the use of BCT to trace food products impacts consumers' perception of product quality as a mediating variable and, consequently, their purchase intention (Treiblmaier and Garaus, 2023). Thus, studies delving into the effective communication of food product attributes to end consumers and the potential impact of BCT on food label systems are currently scarce, though they are gaining notable traction in recent scientific research. As consumers become increasingly conscious of their food choices, there is a growing need to both explore users' intention toward adopting BCT to purchase food products and understand how consumers' perceived transparency of food product information is an important intrinsic mechanism by which BCT experiences affect consumer perceived trust (Liu *et al.*, 2023).

To address this research gap, this paper aims to develop an understanding of how BCT adoption in food label systems might influence consumers' intention toward purchasing labeled food, emphasizing the role of both perceived product transparency and perceived trust. Furthermore, it assesses whether distinct behavioral patterns exist based on demographic characteristics, specifically comparing the intentions of younger generations (Generation Z and Millennials) to those of older generations (Generation X and Boomers) regarding the use of BCT-based food labels.

In line with the research objective, the following research question has been posed:

RQ: How and to what extent can the use of blockchain technology impact consumers' perceptions of food products and their purchase intentions?

To answer this research question and achieve the research aim, this study applies the Unified Theory of Acceptance and Use of Technology (UTAUT) and tests a model that incorporates both perceived trust and perceived product transparency.

This paper is structured as follows: Section 2 is based on the relevant literature, starting with the UTAUT, which provides the theoretical foundation for our study, and then elaborates on blockchain-based traceability systems in the food industry. Section 3 regards the conceptual model and the hypotheses development. Section 4 focuses on the research methodology, then discusses the findings and their implications for both scholars and practitioners. Finally, the concluding remarks, with limitations and future research hints, are provided.

2. Theoretical foundation

2.1 Unified Theory of Acceptance and use of Technology

The UTAUT model, introduced by Venkatesh *et al.* (2003), explains and predicts consumer behavior; therefore, it is one of the most up-to-date models for studying technology acceptance (Mukherjee *et al.*, 2023). In the UTAUT, four preceding factors - performance and effort expectancies, social influence, and facilitating conditions - determine the behavior (use) intention of information technology. The four determinants are the core factors that affect intention and behavior, whereas facilitating conditions directly affect behavior. This study uses the UTAUT to measure users' intention toward adopting BCT to purchase food products.

Among all technology acceptance models, such as the Technology Acceptance Model (TAM - Davis, 1989), the Theory of Reasoned Action (TRA - Fishbein and Ajzen, 1975), and the Theory of Planned Behavior (TPB - Ajzen, 1991), the UTAUT model has been proven to be the superior and most widely used one due to its simplicity, robustness, and parsimony (Tarhini *et al.*, 2016).

The UTAUT has been implemented in past research for the adoption of blockchain in the supply chain (Wong *et al.*, 2020; Francisco and Swanson, 2018), blockchain in the operation and supply chain (Queiroz *et al.*, 2021), blockchain in the retail supply chain (Mukherjee *et al.*, 2023), blockchain in the agri-food supply chain (Sharma *et al.*, 2023a), blockchain in the banking sector (Jena, 2022), and blockchain in the tourism domain (Chang *et al.*, 2022).

2.2 Blockchain-based traceability systems: A focus on perceived trust and product transparency

The food supply chain operates as a complex system, involving a plethora of stakeholders and multiple intermediary processes (Vu *et al.*, 2023). This complexity might lead to information imbalances and potential data loss during transitions. In such a context, BCT, known for its robust and decentralized nature, offers a solution to address issues of food fraud and security (Singh and Sharma, 2023). BCT works as a digital transaction ledger that operates across a computer network without relying on a trusted third party (Treiblmaier, 2018). It consists of unchangeable data blocks, each containing a list of transactions and a unique reference to preceding blocks. The term "blockchain" is sometimes used interchangeably with "distributed ledger," which is a specialized type of distributed database (Rana *et al.*, 2021). This technology assigns distinct digital identifiers to food products, facilitating traceability throughout the supply chain, including information such as batch numbers and expiration dates.

The implementation of a blockchain-based food ledger and transaction registry makes it possible to prevent fraud and establish a means of identifying instances of foodborne illnesses. This approach represents a significant advancement in promoting the sharing of on-farm data (Bumblauskas *et al.*, 2020). Specifically, both data immutability and the distribution among different nodes, each of which shares an identical copy of all recorded transactions, ensures a level of traceability that was not possible before BCT emergence (Treiblmaier, 2019). In this light, Centobelli *et al.* (2021) figured out that the two factors of trust and transparency determine blockchain platform adoption in a supply chain context. Accordingly, Dubey *et al.* (2020) confirmed that using BCT can improve the traceability and transparency of supply chains and enhance the amount of swift trust occurring in temporary organizational structures (Treiblmaier and Garaus, 2023). Therefore, researchers suggest adopting BCT for products for which there is high consciousness of traceability (such as those related to safety and quality concerns, e.g., food products) (Yiannas, 2018; Behnke and Janssen, 2020). Information about a product's attributes, such as its authenticity, integrity, and origin, assures customers of their purchasing decisions (Mingione *et al.*, 2020). In this optic, BCT can allow for the establishment of each of these by enabling trackability, traceability, certifiability, and verifiability (Montecchi *et al.*, 2019). This is because BCT adds a layer of credibility, as its decentralized nature ensures that no entity can delete a previously stored piece of information (Min, 2019).

3. Conceptual framework and hypothesis development

Given the lack of empirical evidence of the adoption of BCT and issues related to trust and perceived product transparency within the food label system, this work seeks to fill this gap by extending the original UTAUT model (Venkatesh *et al.*, 2003) with perceived trust (Yeh *et al.*, 2019) and perceived product transparency (Zhou *et al.*, 2018), as shown in Figure 1.

3.1 UTAUT-related constructs

Performance expectancy (PE) defines the degree to which the use of a new technology can provide individuals with the expected advantages in performing specific activities (Venkatesh *et al.*, 2003). In the context of BCT adoption, up-to-date literature has proved that PE positively influences individuals' intentions (Sharma *et al.*, 2023a). Thus, the following hypothesis has been derived:

H1: Performance expectancy has a positive influence on behavioral intention to purchase blockchain-based labeled food products.

Effort expectancy (EE) is the measure of ease associated with using a system (Venkatesh *et al.*, 2003). In this study, EE indicates the ease of adopting BCT in food labeling. PE and EE are related to each other, as they are aligned toward the system's efficiency, expectations, and effectiveness (Francisco and Swanson, 2018).

Thus, the following hypothesis has been formulated:

H2: Effort expectancy has a positive influence on behavioral intention to purchase blockchain-based labeled food products.

Social influence (SI) refers to the degree to which a person perceives the importance that other individuals assign to using the new system (Venkatesh *et al.*, 2003). Thus, SI regards how people influence the behavior of others in adopting BCT. Sharma *et al.* (2023a) found that SI is highly affected by society's, family members', and friends' beliefs and actions. The following hypothesis captures this relationship:

H3: Social influence has a positive influence on behavioral intention to purchase blockchain-based labeled food products.

Facilitating conditions (FC) indicate the degree to which an individual believes that the organizational and technical infrastructure exists to support the system's use (Venkatesh *et al.*, 2003). In this work, FC concerns the availability of necessary resources to the consumers with regard to using blockchain labels while purchasing food. In addition, in line with Sharma *et al.* (2023a), if there is sufficient technological and human support for BCT, consumers will be more likely to engage with this technology and have a more pleasant experience with it. Based on these arguments, the following hypothesis has been formulated:

H4: Facilitating conditions have a positive influence on behavioral intention to purchase blockchain-based labeled food products.

3.2 Newly added constructs to UTAUT

As stressed in past research, consumer trust forms the basis of product acceptance and long-term relationships with brands (Wu *et al.*, 2021; Siegrist and Hartmann, 2020). An important factor in building trust among consumers is perceived product transparency (PPT - Zhou *et al.*, 2018), especially in the context of food labeling systems (David *et al.*, 2022).

PPT refers to the extent to which consumers can access and understand information about a product and its origin, ingredients, and production processes (Zhou *et al.*, 2018). In this light, as mentioned above, BCT in food label systems provides transparency and traceability in the whole food supply chain, which, in turn, can help consumers make informed choices about the products they purchase, allowing them to trace the journey of a food product from farm to fork (Mollenkopf *et al.*, 2022).

PPT, therefore, represents consumers' perception of the degree to which this information is accessible and trustworthy (Sander *et al.*, 2018). Accordingly, when consumers believe that they have access to reliable and comprehensive information about a product, they are more likely to trust BCT-enabled food label systems (Liu *et al.*, 2023). This leads to the following hypothesis:

H5a: Perceived product transparency has a positive influence on perceived trust.

Prior research (Berry *et al.*, 2015) confirms that consumers often use product labeling as a basis for their purchasing decisions. Likewise, Lee *et al.* (2020) demonstrated that traceable and transparent labels, such as blockchain-based food labels, can increase consumers' purchase intentions. In this regard, the behavioral intention to purchase labeled food products in a blockchain context indicates consumers' willingness to choose and buy products with blockchain-verified labels. Thus, the following hypothesis has been derived:

H5b: Perceived product transparency is positively associated with behavioral intention to purchase blockchain-based labeled food products.

Perceived trust (TR) is a complex psychological construct influenced by various factors, including reliability, credibility, and transparency (Shankar *et al.*, 2002). In a blockchain domain, TR refers to consumers' confidence in the accuracy and integrity of the information recorded on the blockchain (Yeh *et al.*, 2019). BCT's inherent characteristics, such as decentralization and immutability, contribute to the perception of trustworthiness (Singh and Sharma, 2023). Consumers who trust a blockchain-based food label system are more likely to perceive that the information provided about a product is accurate and that the product meets the specified quality and safety standards. TR in such a system can lead to increased intention to buy blockchain-based labeled food products. Hence, the following hypothesis has been formulated:

H6: Trust positively influences behavioral intention to purchase blockchain-based labeled food products.

3.3 The moderating effect of age

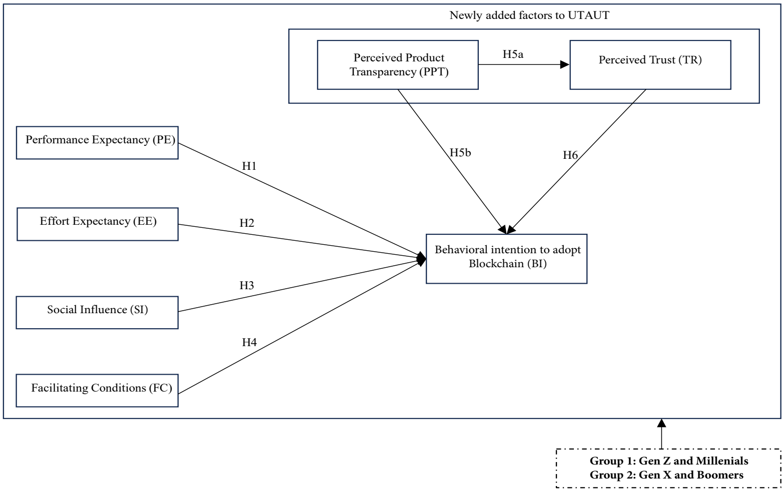
Demographic differences among individuals are associated with their different behavioral intentions (Zhao *et al.*, 2018) to purchase blockchain-based labeled food products.

Specifically, the two younger generations (Millennials, born from 1981 to 1996, and Gen Z, born from 1997 to 2012), both known as digital nomads, share many generational characteristics that are different from those of their counterparts (Garikapati *et al.*, 2016; LaTour *et al.*, 2020; Fan *et al.*, 2023). They are generally considered more tech-savvy and tech-connected than the older generations, such as Boomers (born from 1946 to 1964) and Generation X (born from 1965 to 1976). Additionally, Millennials and Gen Z consumers follow healthy eating habits, and their decisions are linked with sustainable activism (Su *et al.*, 2019). This is in line with the EIT Food research (2021), according to which Millennials and Gen Z people are constantly searching for a healthy food system in which they can actively participate.

Consistent with the theoretical frame of this paper, the following hypothesis has been derived:

H7: Age moderates the effect among UTAUT-related constructs and newly added constructs on behavioral intention to purchase blockchain-based labeled food products.

Fig. 1: The proposed research model



Source: our elaboration

4. Methodology and research design

Measurement items and latent constructs, including PE, EE, SI, FC, and BI, were based on the established scales in order to justify validity (Venkatesh *et al.*, 2003). Likewise, newly added constructs were drawn from previous studies on perceived trust (Yeh *et al.*, 2019) and perceived product transparency (Zhou *et al.*, 2018). All constructs were reflectively measured using multiple-item scales already established in the relevant literature and were slightly adapted to the research context when necessary (Becker *et al.*, 2023).

This study used a hypothetical scenario (or vignettes, as they are sometimes called)[1] (Weber, 1992; Siponen and Vance, 2010), as this enables the examination of consumer decision-making behavior in emerging technology contexts (Della Corte *et al.*, 2023). Specifically, to gather insights into respondents' awareness of and opinions on the use of BCT in the food labeling system, before proceeding with the survey, an image of a QR code on a food product was incorporated into the first part of the questionnaire, along with a brief description of what BCT is and how it functions within the food industry.

After that, the questionnaire constituted two sections: Section A encompassed demographic information, while section B included seven constructs and 25 associated items (see appendix A). A 7-point Likert scale, ranging from strongly disagree (1) to strongly agree (7), was applied to measure the items of each construct.

[1] "Scenarios are defined as descriptions of a person or a social situation which contain precise reference to what are thought to be the most important factors in the decision-making or judgement-processes of respondents" (Weber, 1992, p. 137).

While previous studies had validated most of the items, the adapted measurement items, along with new items, were subject to content validity and reliability in the context of BCT. To ensure content validity, the items and constructs were discussed with three academics who maintained extensive practical and theoretical knowledge about BCT. Following their feedback, an improvement was made: The wording and sequence of the items associated with the perceived product transparency and perceived trust were changed to make them clearer in the context of BCT. The instrument was then pilot-tested with 32 participants. The reliability of measurement items and associated constructs was evaluated such that the Cronbach's alpha value for each construct was higher than the 0.7 threshold (Hair, 2009). The pre-test participants were excluded from the main survey.

The final survey was administered using the LimeSurvey platform from February to May 2023. It gathered 897 answers from university students (enrolled in bachelor's, master's, and PhD courses at the University of Naples Federico II and the University of Suor Orsola Benincasa, Italy) and their relatives. As mentioned above, the rationale for surveying students (Millennials or Gen Z) stemmed from their higher comfort level in utilizing smartphones, a crucial factor for reading QR codes, even during in-store purchases (Ho *et al.*, 2022; Priporas *et al.*, 2017). Additionally, previous studies have frequently employed student samples to gain insights into how younger generations navigate new technologies (Gardner and Davis, 2013; Cavaliere and Ventura, 2018) and make food choices (Steenis *et al.*, 2017; Madilo *et al.*, 2020). At the same time, we gathered responses from Gen X and Boomers to test their propensity for using cutting-edge technology to obtain information about food labels.

After filtering (checking for completeness and correctness), 825 responses were included in the final dataset. Specifically, 559 respondents were in the age group between 18 and 42 years (Gen Z and Millennials), while 226 respondents were in the age group between 43 and 70 years (Gen X and Boomers). The bulk of respondents (68%) attended university courses. In detail, 315 out of 559 students were attending BA courses in Agricultural Science and Marketing & Management, 228 students were enrolled in the MSc programs in Corporate Strategy & Communication and Innovation Management, and 16 were attending PhD courses in Management. Furthermore, the sample maintained the following split: 62% female and 38% male.

5. Results

In this research, behavioral intention (BI) and perceived trust (TR) are the dependent variable. The drivers that affect them are unobservable variables called latent variables (LVs), each measured by several observed indicators usually defined as manifest variables (MVs). Therefore, structural equation modeling (SEM) was considered to be the most suitable statistical methodology for carrying out the analysis.

Data were studied using a PLS-SEM approach, with SmartPLS version 4 (Wong, 2013). This allowed us to focus on predicting the dependent variables and did not require normally distributed data (the Kolmogorov-

Smirnov test showed that no item was normally distributed (P values < 0.001)). Moreover, PLS was recently used in several studies on BCT usage in different contexts (e.g., food supply chain - Khan *et al.*, 2022 and Dehghani *et al.*, 2022; operations and supply chain management - Queiroz *et al.*, 2021; tourism industry - Chang *et al.*, 2022).

Based on Hair *et al.* (2017), a two-stage analytical approach (measurement model and structural model) was applied.

PLS-SEM was implemented, drawing on established procedures and following all recent recommendations (Starsted *et al.*, 2023; Cheah *et al.*, 2023). In particular, the application of CVPAT, which was performed using 10 folds and 10 repetitions as settings, was of the fundamental importance for the assessment of the predict power of UTAUT (Sharma *et al.*, 2023b).

At least, the multigroup analysis (MGA) with age as moderator has been applied. Before performing MGA, the measurement invariance of the composite model routines has been performed (Cheah *et al.*, 2023).

5.1 Measurement model

As all constructs were specified as reflective, the study dealt with the measurement model assessment by examining the reliability (through the Cronbach's alpha scores and composite reliability (CR) of each construct) and validity (both the average variance extracted (AVE) scores and the factor loadings) (Fornell and Bookstein, 1982). As reported in Tab. 1, all loadings were higher than 0.60 (Henseler *et al.*, 2009), each construct's Cronbach's alpha and CR scores were higher than 0.70, and the average variance extracted (AVE) score of each construct was higher than 0.50 (Hair *et al.*, 2017).

Next, discriminant validity, which is one of the key building blocks of model evaluation (Hair *et al.*, 2010), was checked using two criteria: the Fornell-Larcker criterion and the Heterotrait-Monotrait criterion (Henseler *et al.*, 2015). As shown in Tab. 2, the square root of the AVE score for each construct was higher than its highest correlation with the other constructs, and the HTMT ratios were less than the 0.90 threshold. This way, both criteria provided empirical evidence for discriminant validity.

Also, the measurement invariance across the two groups of respondents had been assessed. Measurement invariance must be established before MGA is conducted, to exclude the fact that differences in the estimates are the results of the different content and meanings of the constructs across groups (Hair *et al.*, 2019). Thus, the measurement invariance of composite models (MICOM) routine was applied. Initially, the study ensured that the configuration remained consistent by maintaining uniformity in indicators, data treatment, and algorithm settings for both groups. Subsequently, the MICOM procedure progressed to examine compositional invariance, verifying that the correlations between the composite scores of the two groups remained close to 1. The permutation test (10,000 permutations; Tab. 3) indicated that the null hypothesis for all constructs could not be rejected, confirming compositional invariance (Henseler *et al.*, 2016). Consequently, partial measurement invariance was established, allowing for meaningful comparisons between multiple groups (Hair *et al.*, 2019).

Tab. 1: Validity and Reliability results

Constructs	Items	Outer Loading	Composite reliability (rho_a)	Composite reliability (rho_c)	Alpha	AVE
Performance expectancy (PE)	PE1	0.891	0.930	0.950	0.929	0.825
	PE2	0.923				
	PE3	0.923				
	PE4	0.896				
Effort Expectancy (EE)	EE1	0.898	0.897	0.926	0.892	0.758
	EE2	0.919				
	EE3	0.857				
	EE4	0.802				
Social Influence (SI)	SI1	0.868	0.744	0.841	0.709	0.643
	SI2	0.617				
	SI3	0.892				
Facilitating Conditions (FC)	FC1	0.855	0.848	0.895	0.843	0.681
	FC2	0.862				
	FC3	0.820				
	FC4	0.759				
Perceived Trust (TR)	TR1	0.902	0.841	0.897	0.826	0.746
	TR2	0.923				
	TR3	0.757				
Perceived Product Transparency (PPT)	PPT1	0.923	0.963	0.971	0.963	0.871
	PPT2	0.943				
	PPT3	0.941				
	PPT4	0.954				
	PPT5	0.906				
Behavioral Intention (BI)	BI1	0.964	0.961	0.974	0.961	0.927
	BI2	0.962				
	BI3	0.962				

[a] All constructs are reflective; all items were rated on a 7-point Likert scale, with the extremes being 1 = completely disagree and 7 = completely agree

Source: our elaboration

Tab. 2: Discriminant validity

	BI	EE	FC	PE	PPT	SI	TR
BI	**0.963**	0.872	0.738	0.828	0.744	0.409	0.820
EE	0.807	**0.870**	0.817	0.896	0.851	0.370	0.890
FC	0.669	0.710	**0.825**	0.702	0.794	0.306	0.818
PE	0.782	0.815	0.627	**0.908**	0.761	0.326	0.827
PPT	0.745	0.790	0.718	0.721	**0.934**	0.331	0.895
SI	0.337	0.292	0.231	0.264	0.266	**0.802**	0.367
TR	0.729	0.765	0.684	0.728	0.800	0.268	**0.864**

Note: Fornell-Larcker criterion values are shown below the diagonal, whereas HTMT values are show above the diagonal

Source: our elaboration

Tab. 3: Compositional invariance: results of the permutation test

Latent variable	Original correlation	Correlation permutation mean	5.0% quartile	Permutation p-value
BI	1.000	1.000	1.000	0.968
EE	1.000	1.000	1.000	0.697
FC	1.000	0.999	0.998	0.928
PE	1.000	1.000	1.000	0.586
PPT	1.000	1.000	1.000	0.952
SI	1.000	0.995	0.980	0.997
TR	1.000	1.000	0.999	0.547

Source: our elaboration

5.2 Structural model analysis

The results for the structural model assessment are illustrated in Tab. 4. To test the proposed hypotheses, the path coefficients have been calculated using a bootstrapping procedure (10000 resamples) (Kock, 2018). All hypotheses have been confirmed. The model has been tested for the common method bias (CMB) with the full-collinearity approach. In the analysis, the VIFs were always far below the problematic value of 5, meaning the absence of multicollinearity (Hair *et al.*, 2016; Starstedt *et al.*, 2023). Furthermore, as reported in Tab. 5, R^2 values are above the .10 cut off (Falk and Miller, 1992), suggesting that the model predictive power is good as it explains about 73% of the BI variance and 64% of TR variance. Moreover, Q^2 values support the predictive relevance. Indeed, we obtained a Q^2 higher than 0 (Shmueli *et al.*, 2019).

Tab. 4: Results of structural model assessment and hypotheses testing

HP	Relations	Path coefficients	P values	VIF	Support
H1	PE -> BI	0.292	0.000	3.261	Yes
H2	EE -> BI	0.304	0.000	4.389	Yes
H3	SI -> BI	0.091	0.000	1.101	Yes
H4	FC -> BI	0.094	0.026	2.389	Yes
H5a	PPT -> TR	0.800	0.000	1.000	Yes
H5b	PPT -> BI	0.128	0.012	3.807	Yes
H6	TR -> BI	0.092	0.023	3.428	Yes

Source: our elaboration

Tab. 5: R-square values

	R-Square	Q-square
BI	0.730	0.721
TR	0.641	0.640

Source: our elaboration

Finally, the predict power of the model was assessed using the $PLS_{predict}$ algorithm with 10 folds and 10 repetitions (Shmueli *et al.*, 2019). Specifically, the CVPAT has been applied to evaluate the predictive accuracy of the model against a naïve indicator-averages prediction benchmark and conservative linear model prediction benchmark. The results for the overall model (tab. 6) showed that the model had stronger predictive validity for behavioral intention rather than for trust.

Tab. 6: CVPAT results

Benchmark	Level of analysis: overall model		
		Average loss difference	P value
$CVPAT_{benchmark\_IA\ construct}$	Behavioral intention	-2.183	0.000
$CVPAT_{benchmark\_IA\ construct}$	Trust	-1.419	0.000
$CVPAT_{benchmark\_IA\ overall}$	Overall model	-1.801	0.000
$CVPAT_{benchmark\_LM\ construct}$	Behavioral intention	-0.014	0.463
$CVPAT_{benchmark\_LM\ construct}$	Trust	0.132	0.000
$CVPAT_{benchmark\_LM\ construct}$	Overall model	0.059	0.004

Note: IA = naïve indicator-average prediction benchmark; LM = conservative linear model prediction benchmark

Source: our elaboration

5.3 Multi-group analysis

To examine the moderating effect of age, this study performed a multi-group analysis. A multi-group analysis is often used to compare multiple samples across multiple groups for any identified SEM and to test for significant differences across multiple groups (Papastathopoulos *et al.*, 2020). Before the multi-group analysis, the respondents were divided into two groups based on their age, namely, young people (Generation Z and Millennials, n = 559) and old people (n = 266). Based on tab. 7, all relationships were not supported apart from H6. Thus, the path from TR to BI was moderated by age, while the other relationships were not moderated. Specifically, TR had a statistically significant effect on BI in the young group (standardized estimate = 0.051**) but not in the old group (standardized estimate = -0.004).

Tab. 7: Multigroup analysis with age as moderator

H7		Standardized path coefficient			
Relationships	Young (N = 559)	Old (N = 266)	Difference (old - young)	P-value	Results
PE -> BI	0.292***	0.286***	-0.007	0.472	Not supported
EE -> BI	0.321***	0.260**	-0.061	0.296	Not supported
SI -> BI	0.099***	0.067	-0.034	0.249	Not supported
FC -> BI	0.076	0.148*	0.073	0.207	Not supported
PPT -> TR	0.812***	0.780***	-0.033	0.193	Not supported
PPT -> BI	0.078	0.215**	0.137	0.092	Not supported
TR -> BI	0.151**	-0.004	-0.156	0.034*	Supported

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

Source: our elaboration

6. Discussion

The results of this study contribute to the extant literature arguing that customers are willing to use BCT to purchase labeled food because they perceive BCT to be a dependable foundation ensuring controlled access to information and a reduction in safety and quality risks. Furthermore, BCT allows individuals interested in purchasing a food product to readily validate information, such as its origin and ingredients.

Specifically, all research hypotheses were confirmed, helping not only to augment the existing body of knowledge on the theme under investigation but also to address the RQ: *How and to what extent can the use of blockchain technology impact consumers' perceptions of food products and their purchase intentions?* To address this RQ, this work applied an extended UTAUT model incorporating two new constructs into the original model, namely, perceived product transparency and perceived trust. As for the UTAUT-based constructs (PE, EE, SI, FC), the research's findings confirm their positive impact on BI to purchase blockchain-based labeled food products. On the same page, the newly added factors to UTAUT also show a positive correlation with BI. Precisely, individuals perceive information released by BCT-enabled food labels as being more detailed, transparent, and reliable. This PPT, in turn, positively impacts TR because consumers are more likely to perceive food products as accurate and conform to the specified quality and safety standards. Therefore, both PPT and TR play a key role as antecedents of behavioral intention to adopt BCT when food products are purchased.

Furthermore, to test the moderating effect of age, this study performed a multi-group analysis. The results demonstrated that only TR has a significant effect on BI in the case of Gen Z and Millennials. In the realm of food labels, these tech-savvy generations perceive BCT as a reliable system for tracing the origins and journey of food products. Conversely, Gen X and Boomers, who might be less immersed in the digital landscape, could harbor reservations or be less accustomed to the intricacies of BCT. Thus, the cultural gap and varying levels of technological exposure contribute to a disparity in the trust placed in BCT-based food labels.

The results of this paper offer not only theoretical implications but also practical insights and solutions to the real-world issues that prompted the present research.

7. Theoretical and practical implications

This work contributes both theoretically and practically to current literature.

From a theoretical point of view, as highlighted in past research, blockchain-based food labeling is an important tool for food supply chain participants (Duan *et al.*, 2020). First, producers use it to communicate with consumers and promote their products (Stranieri *et al.*, 2021), while food regulators see it as a means of educating consumers or enforcing food quality standards (Kamble *et al.*, 2020). At the same time, as this study's findings reveal, consumers perceive blockchain-based food labels as relevant sources of information on different product attributes, enabling them to make informed choices.

Moreover, the empirical study affirms the robustness of the extended UTAUT model, as it substantiates the fact that both perceived trust and perceived product transparency play significant roles in influencing the behavioral intention to purchase food label products utilizing BCT. The positive impact observed in the study underscores the importance of these factors in shaping consumer attitudes and behaviors. The validation of the extended UTAUT model provides empirical support for the notion that beyond technological factors, elements such as trust and transparency are crucial determinants in driving consumer acceptance and adoption of BCT-based food products. As both scholars and practitioners navigate the landscape of emerging technologies, acknowledging and incorporating these influential factors into marketing studies and strategies becomes imperative for successful implementation and widespread consumer adoption.

The results also reveal that younger generations trust BCT-based food labeling more than do older generations. In such a context, traversing the post-pandemic landscape underscores the influential role of Millennials and Gen Z in shaping the food industry's trajectory (Orea-Giner and Fusté-Forné, 2023). Their attention to bioactive ingredients, adherence to food safety measures, and preference for sustainable practices are critical determinants that significantly impact the evolution of the food sector (Su *et al.*, 2019). Thus, gaining valuable insights into emerging trends, innovative solutions, and potential shifts in consumer behavior is achievable through the careful monitoring of the beliefs and intentions of these younger generations (Yamane and Kaneko, 2021; Kiliç *et al.*, 2021). This approach contributes to a nuanced understanding of the evolving dynamics within the food industry, providing essential knowledge for informed decision-making and strategic planning. This is in line with Ji *et al.* (2022) I, according to whom supply chain members should focus on the types of consumers in the market to understand consumer psychology.

Additionally, the benefits related to the adoption of BCT recall what has been clearly indicated in a report published by the FAO (2017), according to which strengthening the linkages between farms, markets, and consumers can generate greater income growth and job creation. On the same page, to be profitable within a fiercely competitive landscape, retailers must foster close collaboration with their suppliers. This requires the sharing of comprehensive information about the source and logistics of their products. Hence, enhanced communication with their customers can be a strategic advantage for companies operating in the food industry, as it can boost their competitiveness. Conversely, a dearth of information exchange can have adverse effects, raising concerns among consumers regarding the quality of food products.

With the implementation of BCT, all information generated within supply chains becomes auditable in real-time, offering a means of assessing the credibility and accuracy of this data. This enhances traceability in terms of product transparency and significantly boosts a company's image and reputation, leading to positive effects on customers' purchasing intentions. In these terms, the findings of this work offer another compelling rationale for managers to invest in BCT, as it facilitates communication between all supply chain participants. Specifically, due to the novelty of BCT, companies might experience a collective benefit as both startups and technology incumbents raise awareness of the use of BCT in the food industry. Stemming from another result of this study, consumers' high propensity and heightened awareness could lead to overall growth and opportunities for all parties.

8. Conclusion, limits and future research paths

BCT has rapidly evolved in different industries, including the food sector, to enhance the reliability, traceability, transparency, and trustworthiness of information within supply chains. Consumers in the food industry have become increasingly aware of these factors, thus influencing their purchasing decisions. Surprisingly, the impact of the adoption of BCT on consumer purchase intentions had not been thoroughly examined until now. In such a context, this study has provided preliminary insights into how the utilization of BCT to safeguard label information can positively influence consumer purchase intentions, which can serve as a reliable proxy for actual purchasing behavior.

The findings of this study contribute to a deeper understanding of BCT's role in the food sector, shedding light on its potential benefits on the consumer side. This knowledge, in turn, can be valuable for industry leaders and policymakers, offering evidence to support the broader adoption of BCT in the food industry.

While this study is not without its limitations, it also opens the door to potential directions for future studies. In fact, first, while this research met the required sample size for conducting analyses, there are several avenues for future research that could produce a better understanding of the topic under investigation. Specifically, future studies could increase the number of observations to reinforce the findings of this research. Additionally, researchers could incorporate additional control variables. For instance, the inclusion of institutional and cultural variables (e.g., institutional factors, cultural diversity) in future studies would allow for a more comprehensive examination of the complexities surrounding the decision to adopt BCT in the food industry. Furthermore, while this study focused on consumers' intentions to purchase, future research could directly measure real purchase actions. This would provide a more concrete understanding of how BCT adoption influences consumer buying decisions. Additionally, considering the high implementation costs associated with BCT, future studies could explore the point at which the benefits derived from increased purchase intentions and actual purchases outweigh the overall expenses incurred in implementing BCT solutions.

Moreover, while this study focused on the food sector as an appropriate context in which to study the advantages of BCT in terms of enhancing information trustworthiness and reliability, future research could extend this exploration to other sectors. Such a broader examination might shed light on sector-specific dynamics or ascertain whether similar results can be replicated in different industries.

Lastly, the SEM methodology establishes associations between variables but does not inherently prove causality. Causal interpretations should be made cautiously and ideally be supported by experimental or quasi-experimental designs. Thus, in the future, research should emphasize designing the presentation of traceability information through BCT that aligns with consumers' information preferences. To achieve this goal, qualitative research using focus groups could be a valuable method to explore precisely what kind of information consumers need to effectively assess a product's authenticity. After gaining insights from consumers, researchers can use this information to create user interfaces that effectively convey blockchain-based traceability data. This, in turn, will promote the adoption of BCT in retail and enhance the overall customer experience by providing added value.

In summary, while the present research has shed light on BCT's impact on food label systems, there exist several opportunities for future research that delves deeper, broadens the scope, and promotes deeper comprehension of this evolving field.

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Appendix A: Measurement items

Constructs	Items	Description	Source
Performance expectancy (PE)	PE1	I find the use of blockchain in food labels to be helpful.	Venkatesh et al., 2003
	PE2	The use of blockchain in food labels is beneficial, as it allows me to be more effective in food purchasing.	
	PE3	The use of blockchain in food labels enables me to acquire information more quickly.	
	PE4	The use of blockchain in food labels speeds up the food purchasing process.	
Effort Expectancy (EE)	EE1	Learning how to use blockchain for food labeling is easy for me.	Venkatesh et al., 2003
	EE2	I find using blockchain for food labeling to be clear.	
	EE3	Using blockchain for food labeling is simple, in my opinion.	
	EE4	It is easy for me to become skillful at using blockchain for food labels.	
Social Influence (SI)	SI1	People who are important to me think that I should use blockchain labels while purchasing food.	Venkatesh et al., 2003
	SI2	People who influence my behavior think that I should use blockchain labels when buying food.	
	SI3	People whose opinions that I value prefer that I use blockchain labels when buying food.	
Facilitating Conditions (FC)	FC1	I have the necessary resources to use blockchain labels while purchasing food.	Venkatesh et al., 2003
	FC2	I have the required knowledge to use blockchain labels when buying food.	
	FC3	Using blockchain labels is something I can already do with the technologies I use while buying food.	
	FC4	There are people who can assist me if I encounter difficulties in using blockchain labels while buying food.	
Perceived Trust (TR)	TR1	I trust that using new technologies, such as blockchain, allows tracking the actual place of production of a food product.	Yeh et al., 2019
	TR2	I trust that using new technologies, such as blockchain, allows obtaining accurate information about the production process and the origin of the food product.	
	TR3	Using new ways of interaction, such as blockchain, to purchase food, makes the product more transparent in terms of the information related to its attributes.	
Perceived Product Transparency (PPT)	PPT1	By using new technologies, such as blockchain, for purchasing food products, I could fully understand the product characteristics	Zhou et al., 2018
	PPT2	By using new technologies, such as blockchain, for purchasing food products, I would have a clear idea about the product attributes.	
	PPT3	By using new technologies, such as blockchain, for purchasing food products, I would have a better understanding of the product than other traditional centralized traceability system.	
	PPT4	By using new technologies, such as blockchain, for purchasing food products, I could know the product very well.	
	PPT5	By using new technologies, such as blockchain, for purchasing food products, the product would become more transparent	
Behavioral Intention (BI)	BI1	I intend to adopt new technologies, such as blockchain, when I buy food in the future.	Venkatesh et al., 2003
	BI2	When buying food, I will always try to adopt new technologies, such as blockchain, in my daily life.	
	BI3	When buying food, I plan to continue to use new technologies, such as blockchain, frequently.	

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