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Blockchain and consumer behaviour: Results of a Technology Acceptance Model in the ancient wheat sector

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ABSTRACT

The importance of traceability in food products in regard to consumer preferences, the difficulty of certifications in communicating credence attributes, and concerns about food safety, have led consumers to ask for more information about the credibility of information reported on the label with the product itself, due to the importance of traceability in food products. An objective of this study is to analyze the benefits of implementing blockchain technology in the supply chain for ancient wheat, as a technology capable of sharing reliable information about the products easily along the entire value chain. In particular, the aim is to evaluate how the consumer reacts when confronted with a package of ancient wheat pasta for which all the information on its origin and processing methods is available. In order to achieve these results, a survey based on the Technology Acceptance Model has been developed and conducted in the Italian country. Result indicates the importance of identifying an independent variable that represents the degree of security when faced with a threat that creates a circumstance, condition or event that can lead to economic hardship, for example, data destruction, disclosure, modification, fraud, waste, and abuse. The strength of blockchain lies precisely in its ability to guarantee the immutability of data throughout the supply chain, providing the end consumer with a high-quality product.

1. Introduction

The success of a company is contingent upon fulfilling the needs of its customers, which is why understanding their wants and behaviors is a critical component of each economic agent. In the agri-food sector, consumers are increasingly paying attention to the so-called credence attributes such as production technique and origin (Contini et al., 2016). However, precisely this type of attribute is characterized by the difficulty for the consumer to find information about the accuracy and truthfulness of what reported on the label.

In the agri-food sector, there are various approaches and technologies to certify the origin of food in order to ensure food safety and provide information to consumers (Qian et al., 2020) (Corallo et al. 2020) or as enabler to increase sustainability (Latino et al., 2021).

Labeling is a fundamental tool for certifying the origin of food (Corallo et al., 2019). Foods are labeled with mandatory information such as country of origin, specific geographical area, or place of production. There are also various quality certifications that guarantee the origin and production practices of food. These certifications (e.g., PDO label) may include specific requirements for geographical origin and can be issued by government organizations or independent certification bodies. In the fight against fraud, advanced technologies and analyses (Ben Ayed et al., 2022) can be employed, such as DNA analysis and stable isotopes, which allow for establishing information about the geographical origin of food, or hyperspectral imaging, which can identify the geographical origin of food items like fruits, vegetables, and cereals.

Finally, traceability systems enable tracking the journey of a food product from production to consumption and are increasingly being developed in the industry. These systems utilize technologies such as barcodes, RFID (Radio-Frequency Identification), QR codes, and blockchain to record and monitor information about the origins of food along the supply chain. The use of blockchain, in particular, is assuming an increasingly significant role in the agri-food sector (Rejeb et al., 2020) (Latino et al., 2022) (Li et al., 2023), given its numerous advantages in terms of applicability and scalability and that could prove to be particularly effective in guaranteeing the consumer by protecting him from food fraud. However, the level of knowledge and familiarity that the

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consumer has towards these methods is still to be investigated. Our work is included precisely in this area with the aim of outlining the impacts that the use of these innovations can have on purchasing decisions by analyzing, in a case study, the traditional wheat supply chain. In particular, the purpose of this research is to determine if the consumers are interested in purchasing pasta with transparent information about its origin and production methods, and how this might impact their perception of value.

In order to answer our general question, information about the potential benefits of incorporating Blockchain technology in the traditional wheat supply have been investigate and the following research questions has been defined. RQ1: *Which are the characteristics and software functionalities that can positively act on the using and trust perception of the blockchain technology in the traditional wheat supply chain?* RQ2: *Attitude toward using blockchain technology and products' price positively influence the behavioral intention of the customer?*

Consequently, to answer to the RQs, a questionnaire based on the Technology Acceptance Model (TAM) has been conceptualized and distributed. TAM was developed by Davis in 1989, with modifications made to incorporate relevant variables, as done in previous studies (Davis, 1989, Davis et al., 1989). The TAM model was constructed based on the Theory of Reasoned Action (TRA), developed by Fishbein and Ajzen (1975), which explains an individual's decision to either adopt or reject a technology, in this case, computer usage.

The paper is structured as follows. Section 2 introduce the state of the art of blockchain technology in the agri-food industry, whilst section 3 defines the objectives and the methodology and outline the survey structure and the questions that make it up. Section 4 describe the results of the TAM application, followed by Section 5 where the conclusions are presented.

2. Trust, traceability and blockchain in the agri-food industry

2.1. Traceability and blockchain

The importance of traceability in food products in regard to consumer preferences, the difficulty of certifications in communicating credence attributes, along with concerns about food safety, has led consumers to increase their search for credibility regarding the compliance of information reported on the label with the product itself (Lindgreen et al., 2008; Profeta et al., 2008).

In a trust problem context, economic theory shows how certifications contribute to reducing informational asymmetries connected to product choice, thanks to the participation of actors involved in production in quality assurance systems (Profeta et al., 2008). However, a certification does not solve the credence goods issue but transforms credence into search goods, thanks to consumer trust towards certification bodies. As a result, in the absence of such trust, certifications fail to communicate credence attributes (Lindgreen et al., 2008).

Therefore, while on the one hand regulation on labeling, by regulating information reported on the label, moves in the direction of reducing informational asymmetries through certifications, on the other hand there is a growing demand for reassurance from consumers about the correspondence between product quality attributes and what is reported on it (Galvez et al., 2018; Tian, 2016). In recent years, the demand for transparency has grown significantly, especially in relation to some aspects such as sustainability and the environment (Mol, 2015).

In this context, an important potential innovation capable of ensuring the traceability and authenticity of a product to the eyes of consumers, producers, and other economic stakeholders, is represented by blockchain technology (BCT).

Born in the context of Bitcoin, it can be defined as "a linked list of immutable tamper-proof blocks, which is stored at each participating node" (Gupta, 2017). Thanks to its architecture, it allows the sharing between participants of a ledger that is updated every time a transaction occurs, so that "each participant (node) in the network acts as both a publisher and a subscriber" (Bettín-Díaz et al., 2018).

The BCT has been used in many sectors beyond its initial application in Bitcoin and financial transactions (Tayeb and Lago, 2018). The management of digital signature systems, tracking of intellectual property rights, monitoring of patient health records, and tracking of products in supply chains are some examples of its recent uses (Galvez et al., 2018). In the agri-food sector, many supply chain actors (farmers, processors, distributors, retailers), driven by the need to reduce the informational asymmetry with the consumer, are starting to introduce BCT in order to ensure a superior quality of their processes and products (Antonucci et al., 2019). Its integration into the food supply chain can, in fact, allow for the authentication of the production process traceability, so as to offer the consumer sufficient information on some product characteristics such as origin or production method during the purchase decision. Moreover, with this technology, indications are shown with openness, neutrality, and democracy (Tian, 2017).

Each transaction, once recorded, cannot be modified and is therefore transparent. Transparency is the strength of the blockchain system and is strongly related to consumer trust. In a completely transparent condition, in fact, this system could be considered a valid tool to allow the transformation of credence attributes into search attributes. This is particularly evident for products that carry a denomination of origin or organic certification, i.e. products whose value is currently guaranteed only by trust in the certification on the label (Galvez et al., 2018). In addition to transparency, there are other elements of trust that this tool acts on, namely efficiency, given by the new transactions even among those who do not have trust, and security and safety (Galvez et al., 2018).

2.2. Blockchain applications in the agri-food supply chains

The BCT represents an innovative voluntary certification system capable of increasing transparency, efficiency, security, and safety, even in the food supply chains (Galvez et al., 2018). In this sense, the authentication system ensures that products are in compliance with the information on labels and thus prevents food fraud.

In the food supply chain, BCT allows for the validation of all stages by allowing the registration of different types of information (Kamilaris et al., 2019). In this process, all actors are involved: farmers can record information about their company, such as the geographical coordinates of their plots, the seeds, the pesticides and fertilizers used, the cultivation techniques, and the welfare of the animals; processors can include information about their factory, such as machinery, processes applied to food, and product batch numbers; distributors can record details about the routes, such as travel time and transport conditions (e.g. temperature, humidity); retailers can insert information about quality, expiration date, storage methods, and the time spent on product shelves. Finally, consumers can use their smartphones to scan the QR code on product labels to view all the detailed information about the supply chain that starts with the farmers and ends with the retailers. All supply chain actors accept the information recorded in each step and cannot modify any record (Zhao et al., 2019).

Therefore, in a food supply chain context, BCT can provide a form of guarantee for consumers, for example, on organic products or the origin of PDO foods (Antonucci et al., 2019). Additionally, through the use of analytical techniques (e.g. chromatography, mass spectrometry, DNA, and polymerase chain reaction), it allows certification of the absence of harmful health compounds and GMOs and the actual geographical origin of the ingredients (Galvez et al., 2018). In this sense, BCT constitutes an effective authentication system that aims to protect the consumer's health by preventing food fraud and ensuring the efficiency of processes by avoiding economic losses (Behnke and Janssen, 2019).

Furthermore, the stakeholders in the food supply chain can use BCT not only as a traceability system but also as a marketing tool to improve the reputation of the product, increase customer loyalty, and attract new customers (Dabbene et al., 2014). In this sense, many supermarkets have started to use BCT to verify production methods and track the supply chain of different products under their brand, such as meat, eggs, dairy products, fruit, and vegetables (e.g. Carrefour, 2020; Coop, 2020). Large and small food companies are also starting to use BCT to guarantee the quality of their products. For example, the entire organic pasta supply chain, from wheat sowing to packaging, was certified for the first time by an Italian company using BCT (Aliveris, 2020). The Consortium for the protection of the Red Orange of Sicily IGT has recently introduced BCT to protect oranges from counterfeits and guarantee the quality of the product by monitoring conditions and temperatures during transport and storage (Consorzio Arancia Rossa di Sicilia IGT, 2020).

An Italian company has developed BCT to ensure the traceability of its PGI and organic extra virgin olive oil (Bellucci, 2020). With the help of a smartphone application, it is also able to certify the quality and organoleptic characteristics of the oil contained in each bottle. Implementations of BCT are also found in the alcoholic beverage sector. Several wineries have introduced the technology to allow consumers to access information contained in the intelligent labels of wines, including the geographical location of the vineyard, grape varieties, alcohol content, aging method, number of bottles produced, or awards received (e.g., Placido Volpone, 2020; Ricci Curbastro, 2020). This innovation is starting to spread in Ireland and Canada among craft breweries that share information with consumers about the ingredients used and brewing methods of their beers. From the examination of numerous BCT implementation examples, it appears that this technology is spreading in the agri-food sector to make production and distribution of food more transparent, safe and sustainable. However, there are still technological, legal and economic issues that limit its development (Behnke and Janssen, 2019; Kamilaris et al., 2019). Research on technological issues appears more developed (Galvez et al., 2018; Zhao et al., 2019), while studies on consumer preferences, trust and willingness to pay for the use of BCT in food chains are still limited (e.g., Parra-López et al., 2021). The results of early research show that consumers have positive perceptions of BCT implementation and are willing to pay a higher price when this system represents an actual guarantee of quality, transparency and origin (Violino et al., 2019). However, there is a need to deepen the theme, evaluating for example if there are differences when BCT is associated with different food chains or other certifications (Parra-López et al., 2021).

3. Objective, methodology and research model

The aim of this work is to design a survey to collect data on the benefits of implementing blockchain technology in the supply chain of ancient wheat. In particular, the aim is to evaluate how the consumer reacts when confronted with a package of ancient wheat pasta for which all the information on its origin and processing methods is available.

3.1. Research model

A small number of studies have explored consumer acceptance of Blockchain technology across different industries (N. Liu and Ye 2021; Pérez-Sánchez et al. 2021; Albayati, Kim, and Rho 2020; Shrestha and Vassileva 2019, Chen et al. 2022, Wang and Liu 2022), but there is no existing research on consumer acceptance of Blockchain in the agri-food sector. The literature suggests that the Technology Acceptance Model (TAM) is widely used as a starting point for technology acceptance research, across various industries and sectors. The definition of a theoretical framework based on the adoption of TAM (Technology Acceptance Model) strengthens the scientific rigor of the study and contributes to expanding knowledge in the field of research on technology diffusion and innovation adoption. The theoretical model has been developed to explain and predict user behavior towards new technologies in an important but still relatively unexplored area such as the agri-food sector. TAM has provided a conceptual framework for better understanding how individuals perceive and adopt new technologies, examining key factors influencing the intention to use a technology, such as utility and ease of use. The results obtained using the TAM approach can help predict the adoption of blockchain, enabling companies and developers to better understand the potential success of a product or service in the market. The model also provides strategic insights for designing more intuitive and user-friendly user interfaces, focusing on ease of use to enhance the acceptance and adoption of new applications and systems.

As such, TAM has been identified as the research model for this study to determine the intention to use Blockchain technology as an anti-counterfeiting tool in the ancient grain supply chain. However, due to the limitations of TAM in explaining the adoption of new Information and Communication Technology (ICT) (Bandinelli, Fani, and Rinaldi 2017), additional constructs have been included to complement the model.

The proposed model follows the approach used by Davis in his “Technology Acceptance Model” study and takes into consideration the following determinants: Perceived Usefulness, Perceived Ease of Use, Attitude Toward Using, and Behavioral Intention. Additionally, the model includes the variables of Perceived Trust, Perceived Security, Perceived Privacy, and Price Value, while excluding External Variables (Figure 1).

We considered Perceived Usefulness, Perceived Ease of Use, Perceived Security, Perceived Trust, Perceived Privacy and Price Value as antecedents of Attitude Toward Using or Behavioural Intention and we wanted to test the following seven hypotheses.

- H1: Perceived Usefulness acts positively on Attitude Toward Using
- H2: Perceived Ease of Use acts positively on Attitude Toward Using
- H3: Perceived Security positively acts on Perceived Trust
- H4: Perceived Privacy acts positively on Perceived Trust
- H5: Perceived Trust acts positively on Attitude Toward Using
- H6: Attitude Toward Using acts positively on Behavioural Intention
- H7: Price value acts positively on Behavioural Intention

A survey was designed based on the selected constructs and created using the Google Forms application. The questionnaire consists of two parts: the first asks personal questions to categorize the respondents, and the second contains questions related to the selected constructs. The survey uses a four-point Likert scale ranging from “strongly disagree” (1) to “strongly agree” (4) to measure the constructs. The use of a “no-midpoint” Likert scale was chosen to minimize the risk of respondents converging on the neutral answer, which was identified as a concern in pilot tests (Bandinelli, Fani, and Rinaldi 2017). The survey was disseminated through email, messaging apps, and social media platforms to reach a large audience.

3.2. Survey presentation

For the creation of the survey, as previously written, we started from the Davis’ TAM model by considering the constructs: Perceived Usefulness, Perceived Ease of Use, Attitude Toward Using and Behavioural Intention with the exclusion of External Variables as well as Perceived Trust, Perceived Security, Perceived Privacy and Price Value. Based on these constructs and literature it was possible to perform the following hypotheses:

3.3. H1: Perceived Usefulness acts positively on Attitude toward using

Users are only willing to adopt innovations if they offer a unique advantage over existing solutions (Rogers 1995). This view is reflected in TAM’s Perceived Usefulness construct, which is the degree to which a person believes that the use of a particular system will improve his or her job performance (Davis 1989). Davis demonstrated the relevant influence of Perceived Usefulness on Attitude Towards Use. In order to study this phenomenon, applied to the model under study, three questions

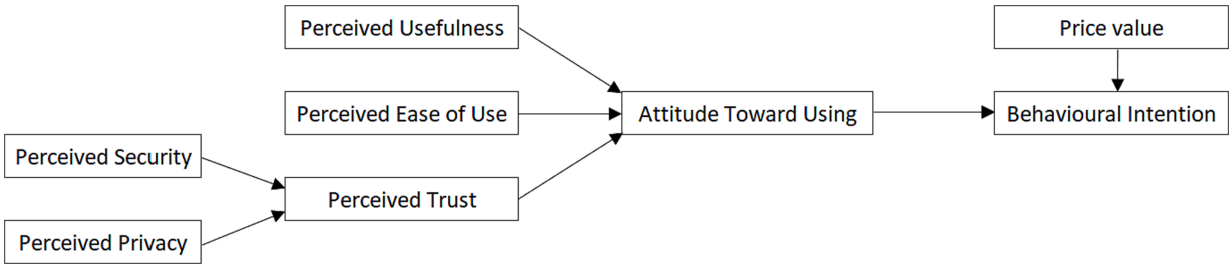

Fig. 1. Model proposed for this study.

were asked, measured with a four-point Likert scale, which indicates the degree of relevance that these items have for the respondent, starting from a minimum level equal to 1 (indicating total disagreement) to a maximum level equal to 4 (indicating total agreement).

3.4. H2: Perceived Ease of use acts positively on Attitude toward using

Perceived ease of use is the degree to which a person believes that using a particular system would be effortless (N. Liu and Ye 2021; Davis 1989 Pérez-Sánchez et al. 2021; Albayati, Kim, and Rho 2020; Shrestha and Vassileva 2019). According to TAM, perceived ease of use has been shown to have a significant impact on attitude towards the use of a wide range of technologies. It has been shown that people are more likely to consider using a new technology if it is effortless or at least not overly complex. In order to test this hypothesis, three items were used, which were also extrapolated from the literature (Davis et al. 1989). The aim is to analyse the consumer's perception of the effort required to learn how to use the system and the possible influence of this determinant on the attitude towards the use of the technology.

Perceived security has been defined as "a threat that creates a circumstance, condition, or event with the potential to cause economic hardship in the form of destruction, disclosure, modification of data, fraud, waste, and abuse" (Kalakota and Whinston 1997). Security, which includes the use of advanced technologies such as encryption, digital signatures and certificates to protect users from risks, has a positive impact on the intention to use new technologies (Lian and Lin 2008; Roca, García and Vega 2009). The use of this construct aims to understand whether consumers perceive the security of the blockchain, and thus understand the benefits that a blockchain-tracked product has over a non-blockchain-tracked product.

Positive or negative perceptions of privacy arise from the fact that online companies collect sensitive information about individuals that could be used inappropriately. There is growing concern about the security and use of information provided on the web. Consumers hesitate to provide personal information to online companies because of fears that information sent over the Internet could be intercepted, misused or shared with other organizations (Roca, García and Vega 2009a). Therefore, when security and privacy policies are disclosed and made explicit, consumer confidence increases (Chellappa and Pavlou 2002). The hypothesis aims to test the impact that perceived privacy has on perceived trust, which in turn will have an impact on usage attitudes.

Trust has been analysed in many disciplines, including social psychology, e-commerce and e-banking. Roca, García and Vega (2009) define trust as "a person's behaviour based on beliefs about another person's characteristics". Since the degree of uncertainty is higher in a virtual context than in a traditional one, trust has become an important factor. Therefore, we would like to analyse the behaviour and reactions of users regarding the variable trust towards blockchain.

For the construct of Behavioural Intention, a dependent variable, three items were used.

The cost and price structure can have a significant impact on consumers' use of technology. In marketing research, monetary cost/price is usually conceptualised together with product or service quality to determine the perceived value of products or services. Venkatesh, Thong, and Xu (2012) define price value as consumers' cognitive trade-off between the perceived benefits of applications and the monetary cost of using them. The price value will be positive if the benefits of using the technology are perceived to be greater than the monetary cost, and such a price value will have a positive impact on the intention to use.

Hereafter, the hypothesis, the constructs, the definitions and the items are reported in Table 1.

The seven hypotheses were tested using a structural equation model (SEM). In its general form, the SEM consists of a set of linear equations that simultaneously assess the relationships between the observed variables (items) and the unobserved (latent) variables, i.e. the constructs measured by the items. In general, a SEM consists of two parts. The first, called the measurement model, expresses the relationship between the latent variables and the observed scores. The second part describes the causal relationships between the latent constructs and is referred to as the structural part (Bollen and Davis 2009). The SEM specification procedure was carried out in three stages. In the first step, the coherence of the items used for each latent construct was checked by calculating the corresponding Cronbach's alpha. Then, a Confirmatory Factor Analysis (CFA) was performed to check the overall goodness of fit of the model, the reliability and the significance of each item. On the basis of these two analyses, the items were then selected for use in the final model, which contains the structural part of the relationships between the latent variables. The reliability of the scale was tested using Cronbach's alpha coefficient (α) according to several authors. The alpha coefficient is considered adequate for values of 0.70 or higher (Fornell and Larcker 1981).

4. Results

A survey has been designed to collect data on the benefits of implementing blockchain technology in the supply chain of ancient wheat in order to test our seven hypothesis (H1-H7). In particular, the aim is to assess how the consumer reacts when confronted with a package of ancient grains pasta for which all the information on its origin and processing methods is available.

The questionnaire was distributed by email, messaging applications and published on social networks from July to October 2022 collecting 366 records, representative of Italian population for age and gender, of which one was rejected because it was not compliant. The exact number of respondents is half male and half female and most of these are in the age groups or between 18 and 30 or between 41 and 55. Most of the respondents have a high school degree or qualification greater. A large proportion of respondents are either employed or self-employed. It is very interesting to note that about 2/3 of the respondents have never heard of blockchain technology. Most of the interviewees pay attention to the origin of the wheat when they buy a package of pasta. Only 1/3 usually buy ancient grain pasta.

SEM requires an adequate sample size to obtain reliable and meaningful results. Sample size considerations are crucial to ensure statistical power, model identification, and accurate estimation of model parameters. Holye et al. (2015) found that samples with $n < 100$ can generate

Table 1
Construct, description and items.

HYPOTESIS	COSTRUCT	DEFINITION	ITEMS
H1: Perceived Usefulness acts positively on Attitude Toward Using	Perceived Usefulness (Davis 1989; Davis et al. 1989)	"The subjective probability, for potential users, that using a specific application system increases work performance within an organizational context"	Using this system is useful Using this system allows me to quickly know where what I buy comes from Using this system simplifies my choice during the purchase
H2: Perceived Ease of Use acts positively on Attitude Toward Using	Perceived Ease of Use (Davis 1989; Davis et al. 1989)	"The degree to which the potential user expects the use of the system to be effortless"	Learning to use the system would be for me (easy - difficult) The use of the system is for me (easy - difficult) Interacting with the system requires (a lot of mental effort - little mental effort)
H3: Perceived security positively acts on Perceived Trust	Perceived Security (Roca, De la Vega 2008)	"A threat that creates a circumstance, condition or event with the potential to cause economic hardship in the form of destruction, disclosure, modification of data, fraud, waste and abuse"	I think this complex technology is such that it ensures that the product I buy is of high quality The system has sufficient security measures to ensure that the information is true I think the technical operation of the system is efficient enough to ensure that the product is not counterfeit
H4: Perceived Privacy acts positively on Perceived Trust	Perceived Privacy (Roca, De la Vega 2008)	"Positive or negative perception that online businesses collect sensitive information about individuals, which could be used inappropriately"	I am concerned that the system uses my personal information for other purposes, without my permission I think too much personal information will be collected I think information about my consumption habits will be collected
H5: Perceived Trust acts positively on Attitude Toward Using	Perceived Trust (Roca, De la Vega 2008)	"A person's behaviour based on certain beliefs."	This system seems reliable This system has a good reputation I do not question the honesty of the system
H6: Attitude Toward Using acts positively on Behavioural Intention	Attitude Toward Using (Davis et al. 1989)	"Attitude towards a particular technology"	I think using the system is an idea (good - bad) The idea of using the blockchain intrigues me I think using blockchain is a waste of time

Table 1 (*continued*)

HYPOTESIS	COSTRUCT	DEFINITION	ITEMS
	Behavioural Intention (UTAUT, Venkatesh et al. 2003)	"Willingness to actually use the system"	I plan to use the system in the future I intend to use the system in the future I would like to use the system in the future
H7: Price value acts positively on Behavioural Intention	Price Value (Venkatesh et al. 2012)	"The consumer cognitive trade-off between the perceived benefits of applications and the monetary cost of using them"	I am willing to spend more to get information on the origin and quality of a packet of ancient grains pasta than one that does not I intend to buy a packet of ancient grains pasta that has information on its origin and traceability. I would rather buy one that does not, even if it costs me more. I plan to spend more on a package of ancient grains pasta of which I know the origin and quality than one of which I do not know this information

issues in model stability and power. In our case, a sample with n = 366 records and a number of latent variables equal to 8 is deemed consistent (Iacobucci, 2010).

The questionnaire that was disclosed in Italian can be consulted in the appendix. The demographic characteristics of the sample are presented in Table 2.

The survey also included questions related to the interviewee's knowledge and awareness of blockchain technology, as well as their purchasing habits for ancient grains pasta. The responses to these questions were recorded and the results are presented in Table 3.

Table 2
Sample's demographic characteristics.

Characteristics	Sample	
Age	18—30	123
	31—40	37
	41—55	134
	Over 55	72
Gender	Female	183
	Male	183
	I prefer not to specify it	0
Educational qualification	Graduation	218
	High school diploma	124
	Middle school diploma	24
	Primary school diploma	0
Profession	Student	79
	Self employed	85
	Worker	8
	Employee	174
	Unemployed	4
	Pension	15

Table 3
Knowledge of the blockchain and purchasing habits.

Questions	Yes	No
Have you ever heard of blockchain technology before?	132	234
When buying a package of pasta, do you pay attention to the origin of the wheat?	223	143
Do you usually buy ancient grains pasta?	131	235

4.1. Structural model

The first step for the development of the SEM is the analysis of the constructs. Table 4 shows the Cronbach's alpha results for each construct, highlighting the reliability of our data. A CFA was estimated to validate the measurement model and to test item reliability. A test of normality was performed first. The Mardia's normalised estimate of multivariate kurtosis shows a chi-square = 1630.056 with one degree of freedom and a p-value = 0.00. We therefore reject the null hypothesis of multivariate normality. In the situation of non-normality of the data, the goodness of fit and the significance of the parameters may be biased. For this reason, we first performed an analysis without corrections and then applied the Satorra-Bentler correction.

The convergent validity of the scale items and their ability to discriminate between constructs were checked using the main methods proposed in the literature. The construct validity of the measurement model was examined. Table 13 shows the results of the measurement model with and without the Satorra-Bentler correction; all 24 items have standardised factor loadings that are statistically significant and greater than the recommended minimum cut-off of 0.50 (Fornell and Larcker 1981). This supports the convergent validity of the scale items. In addition, convergent validity was examined using two parameters: average variance extracted (AVE) and composite reliability (CR) (Table 4). According to the criteria proposed by Fornell and Larcker, the composite reliability should exceed 0.7 and the average variance extracted by each construct should exceed the variance due to measurement error for that construct (i.e. AVE should exceed 0.5). The perceived privacy constructs have an AVE greater than 0.7, which is the more stringent threshold defined by Fornell and Larcker (1981). The remaining constructs have acceptable values (greater than 0.5). The CR of the measurement model ranges from 0.60 to 0.94, thus exceeding the recommended minimum standard. Convergent validity of all scales can therefore be assumed.

Finally, we assessed the discriminant validity through the heterotrait-monotrait ratio (HTMT) of the correlations (Henseler, Ringle, and Sarstedt 2015). Table 5 shows the HTMT ratio values without correction, while Table 6 shows the HTMT ratio values with the Satorra-Bentler correction. In both cases, the correlations are all below

Table 5
Results of heterotrait-monotrait ratio analysis without correction.

	PU	FUP	SP	PP	FP	AVU	VP	IC
PU	1							
FUP	0,388	1						
SP	0,279	0,447	1					
PP	-0,017	0,203	0,22	1				
FP	0,265	0,399	0,766	0,22	1			
AVU	0,419	0,501	0,629	0,296	0,781	1		
VP	0,424	0,202	0,399	-0,036	0,266	0,368	1	
IC	0,373	0,574	0,477	0,156	0,374	0,584	0,476	1

Table 4
CFA results – Measurement and reliability of constructs.

Items	Cronbach's alpha	No corrections Factor Loadings	Average variance extracted	Composite reliability	Satorra - Bentler correction Factor Loadings	Average variance extracted	Composite reliability
Perceived Usefulness (PU)	0,807		0,590	0,812		0,589	0,812
PU1		0,766			0,754		
PU2		0,792			0,781		
PU3		0,746			0,769		
Perceived Ease of Use (PEU)	0,775		0,590	0,804		0,590	0,805
PEU1		0,825			0,822		
PEU2		0,903			0,902		
PEU3		0,522			0,531		
Perceived Security (PS)	0,856		0,679	0,862		0,680	0,863
PS1		0,69			0,698		
PS2		0,902			0,899		
PS3		0,864			0,863		
Perceived Privacy (PP)	0,866		0,701	0,874		0,702	0,874
PP1		0,804			0,809		
PP2		0,974			0,966		
PP3		0,713			0,719		
Perceived Trust (PT)	0,819		0,587	0,810		0,603	0,820
PT1		0,786			0,808		
PT2		0,751			0,756		
PT3		0,761			0,765		
Attitude Toward Using (ATU)	0,845		0,599	0,817		0,651	0,848
ATU1		0,839			0,873		
ATU2		0,763			0,793		
ATU3		0,715			0,751		
Price Value (PV)	0,84		0,639	0,841		0,639	0,841
PV1		0,765			0,764		
PV2		0,853			0,858		
PV3		0,777			0,772		
Behavioural Intention (BI)	0,929		0,792	0,920		0,816	0,930
BI1		0,884			0,899		
BI2		0,887			0,899		
BI3		0,899			0,912		

Table 6
Results of heterotrait-monotrait ratio analysis with Satorra-Bentler correction.

	PU	FUP	SP	PP	FP	AVU	VP	IC
PU	1							
FUP	0,15	1						
SP	0,078	0,2	1					
PP	0	0,041	0,049	1				
FP	0,07	0,159	0,587	0,129	1			
AVU	0,176	0,251	0,395	0,088	0,609	1		
VP	0,18	0,041	0,159	0,001	0,071	0,135	1	
IC	0,139	0,33	0,227	0,024	0,14	0,342	0,226	1

Table 8
Hypothesis test result.

	Hypotesis			Estimates	S.E.	p-value
H1	ATU	←	PU	0,217	0,054	*
H2	ATU	←	PEU	0,258	0,057	***
H3	PT	←	PS	0,74	0,040	*
H4	PT	←	PP	0,234	0,044	**
H5	ATU	←	PT	0,707	0,047	*
H6	BI	←	ATU	0,489	0,056	***
H7	BI	←	PV	0,326	0,052	***

* < 0,0001 ** 0,0005 ***0,0009

the cut-off value of 0.85 reported by Henseler et al. (2015). According to these results, we can assume that all constructs meet the requirement of discriminant validity.

To conclude, the constructs and their measures show good reliability and validity. This enables us to estimate the structural part of the model.

The SEM was constructed by modifying the measurement model by inserting structural relationships between the latent variables (based on the hypotheses from H1 to H7). Table 7 shows the measurement and structural model fits with and without correction. The estimated structural model shows an overall good fit, although it is slightly worse than the measurement model. This result is probably due to the fact that there are not too many respondents compared to the complexity of the model. Similar results can also be found in the literature, as reported, for example, by Bandinelli, Fani and Rinaldi (2017). We can observe that the model with Satorra-Bentler corrections gives better results than the one without corrections. In particular, the Satorra-Bentler scaled chi-square of the structural model is equal to 1.73 (=406.572/235); the CFI is equal to 0.961 and the RMSEA is equal to 0.045 (Table 16).

From now on, we will use this model as a reference, since the structural model fits better with Satorra-Bentler corrections.

In order to validate the results of the hypotheses, a path analysis was carried out based on the p-value. The results of the hypothesis test are shown in Table 8 and the whole structured model is shown in Figure 2.

We can see that all constructs are statistically significant. PU has a positive significant casual relationship with ATU (b: 0.217), as does PEU (b: 0.258). PS and PP are both positively correlated with PT (b: 0.740; b: 0.234), which in turn has a positive influence on ATU (b: 0.707). In addition, ATU has a significant positive relationship with BI (b: 0.489). PV also has a positive impact on BI (b: 0.33).

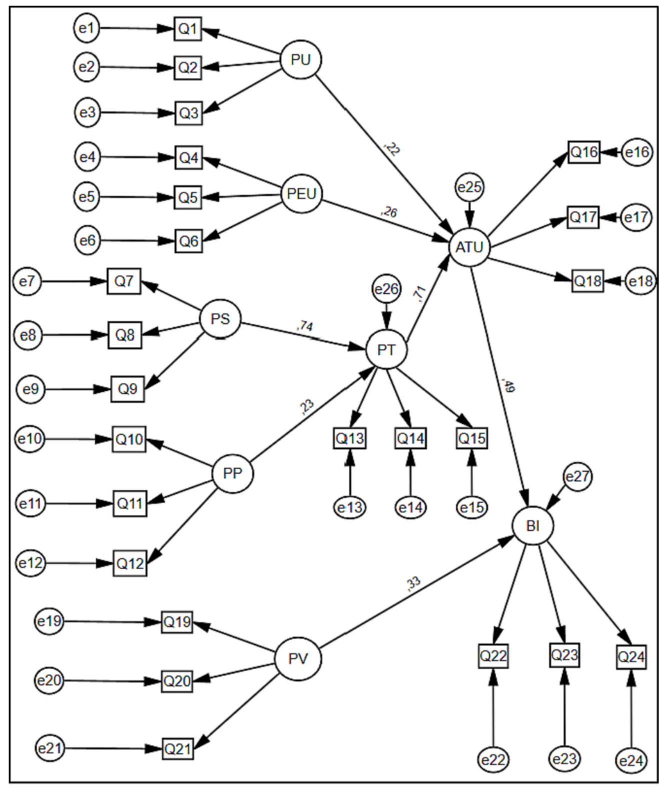

Fig. 2. Standardized parameters of the structural model.

5. Conclusion

The main goal of this work is to evaluate if the consumer is interested in buying a packet of ancient grains pasta of which all the information about origin and processing methods is available. This research question can be translated into analyzing which are the determinants in customers' behavior intention of use for blockchain technology in the ancient wheat supply chain.

The results of the survey were tested using structural equation modelling (SEM). The analysis consists of two macro parts: the first is a measurement model analysis and the second is a structural model analysis. We performed a statistical test to determine whether the data distribution was normal. The test gave a negative result and therefore the Satorra-Bentler correction was applied to the goodness of fit of the model compared to the saturated model. We first tested the consistency of the items used for each latent construct by calculating Cronbach's alpha. This gave a positive result, in fact it is always greater than 0.7 for each construct. We then calculated the average variance extracted and the composite reliability, all of which gave acceptable values. The discriminant validity also gave a positive result. So the constructs and their measures show a good degree of reliability and validity. We then looked at the structural model. The model fit indices all gave good results as they were all better than the recommended values. A path analysis was carried out based on the p-value.

The result of the SEM analysis highlights the importance of the independent variable PS. PS represents the degree of security in the face of a threat that creates a circumstance, condition or event with the potential to cause economic hardship in the form of destruction, disclosure, modification of data, fraud, waste and abuse. The strength of blockchain

Table 7
Measurement and structural model fits.

Goodness of fit mesure	Reccomended value	No correction Measurement model	Structural model	Satorra-Bentler correction Measurement model	Structural model
χ^2/df	≤ 3,00 (Wang & Wang, 2010)	1,805	1,998	1,573	1,73
CFI	≥ 0,90 (Bagozzi & Yi, 1988)	0,965	0,955	0,970	0,961
RMSEA	≤ 0,05 (Steiger, 1980)	0,047	0,052	0,040	0,045

lies precisely in its ability to guarantee the immutability of data throughout the supply chain, providing the end consumer with a high-quality product. Although around 2/3 of respondents had never heard of blockchain, they would welcome a system that would allow them to track the product throughout the supply chain, further improving the final quality. Consumers need to be informed and know everything about the product they are buying.

According to many TAM studies, such as Albayati, Kim and Rho (2020), Chellappa and Pavlou (2002), Lian and Lin (2008), the survey results confirm that when the consumer has confidence in the technology being implemented, he is very inclined to use it, in fact PT correlates very positively with ATU with a value of 0.71. Too many food scares in recent years have opened the eyes of consumers who need a tool they can trust.

PU and PEU have a positive influence on ATU, although to a lesser extent than PT, which plays a fundamental role. A similar result is reported by Roca, García and Vega (2009), where PT has a greater influence on BI than PU and PEU.

Another very interesting result, which confirms the one found by Venkatesh, Thong, and Xu (2012), concerns PV. In particular, PV represents the consumer's cognitive trade-off between the perceived benefits of the applications and the monetary cost of using them. We can see that consumers are willing to spend a higher amount to enjoy a product whose origin and traceability information is available.

PP is one of the least influential variables. This suggests that consumers are concerned about online companies collecting sensitive information about them that could be used inappropriately.

The consumer's positive attitude towards a given technology strongly influences the willingness to use it, and this is confirmed by most of the case studies in the literature.

This is the first study using the TAM methodology to evaluate consumer behavior in front of a blockchain-tracked package of ancient grains pasta.

The theoretical framework has proven to be suitable for analyzing the impacts of the new technology on consumers, even in a previously underexplored sector such as the agri-food industry. The TAM approach has enabled us to understand how industry actors perceive the benefits of blockchain technology for improving traceability and transparency, and how these perceptions influence their intention to use blockchain to ensure the origin and quality of food products. Moreover, the TAM approach has helped us to examine how security and trust affect the opinions of industry actors and their adoption of the technology. In this context, the results obtained serve as a starting point to identify perceptions regarding the ease of using blockchain technology for information sharing among chain participants and to understand how industry actors assess the costs and benefits of adopting the technology, influencing their decision to invest in it. The application of the Technology Acceptance Model in the agri-food sector provides an in-depth insight into the perceptions and intentions of industry actors. This has allowed us to identify key factors influencing the acceptance of blockchain and to develop targeted strategies to promote the adoption of this innovation in the agri-food sector.

The results of this study suggest that consumers value this technology, in particular the fact that the blockchain provides truthful information about the origin of what they are eating. The main implications of the potential that this technology can have in the agri-food sector involve, on one hand, engineering research related to the development of increasingly intuitive and simple protocols for industry operators, and on the other hand, the implementation of marketing and communication actions to increase consumer awareness and trust. As a matter of fact, BCT may constitute an important tool, even though our study raises the issue of correctly communicating the mechanism that regulates it, so that the consumer can understand its effectiveness in guaranteeing transparency and accountability. This passage indeed appears essential for the blockchain to contribute to strengthening trust in the credence attributes and the reliability of the already existing quality signals, instead of seeming to be simply more information that increases the complexity of choosing for the consumer (Grunert, 2005; Parra-López et al., 2021).

It is worth noting, finally, that cost constitutes one of the main factors hindering the adoption of blockchain technology in the agri-food sector (Kunpeng et al., 2023). The implementation of a blockchain network indeed requires significant financial resources, both for the establishment of the hardware infrastructure and for its management. Therefore, stakeholders considering the adoption of this technology will have to compare the costs of implementation and management with the actual willingness of consumers to pay (Zhang et al., 2022).

These considerations provide cues for future developments of study, which should examine the consumer's actual knowledge of the blockchain mechanism and study, if need be, the means to instruct the consumer about how BCT functions.

Directly connected to this aspect, our work leaves unexplored the issue of how to communicate to the consumer the presence of a traceability mechanism based on BCT. Furthermore, the willingness to pay (WTP) of consumers for products whose origin is traced through blockchain certainly deserves further investigation. This strategic information, in fact, would allow for a more effective assessment of the economic sustainability of implementing the technology on the part of companies. Finally, it would be interesting to analyze the potential of BCT on other products beyond pasta. The outcomes of these studies would expand the informational framework in order to steer more effectively the communication campaigns on the capabilities of BCT to keep account of the supply chain of foods, strengthening the role of certifications, promoting informed choices of the consumer and stimulating their proactive role in the objectives of environmental and social sustainability and public health. The main limitations of our analysis are related to the fact that we only considered consumers in Italy and did not investigate the economic condition of the respondents.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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