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Consumers’ valuations of tea traceability and certification: Evidence from a blockchain knowledge experiment in six megacities of China

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ABSTRACT

Blockchain-based traceability provides unforgeable and tamper-resistant traceability information, thus contributing to a high-quality and safe food supply and alleviating consumers’ increasing concerns about food quality and safety. There is scant literature analyzing consumers’ valuation of blockchain-based traceability, although it matters for the application and development of this technology. We investigated the consumers’ valuation of blockchain-based traceability in the tea industry in China. We conducted a randomized experiment to estimate the effect of the information intervention on consumers’ valuation. Using data from 4017 respondents in six Chinese megacities collected from an online survey, we found that consumers valued blockchain-based traceability more than commonly-used quality assurance attributes, including conventional traceability and certification labels, and consumers viewed blockchain-based traceability and certification labels as substitutes. Furthermore, exposure to relevant knowledge increased their valuation of blockchain-based traceability. This was especially true for consumers valuing product quality and safety most and young, highly educated, and high-income consumers. We suggest stakeholders strengthen publicity to help consumers realize the value of blockchain-based traceability technology.

1. Introduction

Certification has been widely used in the food supply chain to address the frequent occurrence of food scandals, which arouses severe public concerns about food quality and safety. It is difficult for consumers to verify food quality and safety because it can be an experience or credence attribute (Antle, 2001; Hobbs, 2004). To reduce information asymmetry and rebuild consumers’ confidence, various quality assurance strategies, including certification, have been adopted worldwide (Meuwissen et al., 2003; Moschini et al., 2008). However, the information conveyed by certification labels, though straightforward, is usually limited to only a single feature (Jin & Zhou, 2014) and thereby cannot satisfy the increased demand of consumers for the identification of the quality and safety of products (Islam & Cullen, 2021).

With much more information than certification, food traceability has received increasing attention. Food traceability means the connection of all different stages, from production, processing, and distribution, to consumption of food (European Union, 2002). A well-established traceability system not only enables the ex-ante quality verification and information disclosure for consumers but also facilitates the ex-post traceback of affected products and the allocation of liability in the event of a food quality and safety problem (Golan et al., 2004; Hobbs, 2004). However, a conventional traceability system usually relies on a centralized data storage pattern, where it is technically feasible for the stakeholder who manages the data to tamper with the data arbitrarily (Fan et al., 2020; Lin et al., 2019). It is particularly true when tampering is more profitable for the stakeholders, although it is illegal. In sum, the centralized traceability system is not reliable enough to ensure quality and safety regardless of which organization endorses them (Lin et al., 2020).

The blockchain-based traceability system is superior in food traceability with decentralization, transparency, and authenticity. Blockchain is a shared and distributed ledger system in which each entity keeps a copy of all the records. The data is recorded based on the consensus between the entities involved, and the records can only be altered if more than half of the entities approve the modification (Collart & Canales, 2021; Galvez et al., 2018; Mirabelli & Solina, 2020). Therefore, blockchain-based traceability can provide more trustworthy

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information for consumers to verify food quality and safety, owing to data unforgeability and tamper resistance (Galvez et al., 2018; Mirabelli & Solina, 2020).

The applications of blockchain-based traceability in the food supply chain have emerged in the global community, including China. In the United States, the *Blockchain Promotion Act of 2019* was approved to encourage the broader application of blockchain in food traceability and supply chain management (Congress, 2019). One of the famous cases is the collaboration between the IBM food trust and the retail food giant Walmart (Shew et al., 2021; Yiannas, 2018). So far, blockchain-based traceability is mostly applied to high-value, high-volume perishable goods like beef due to the high cost of system establishment (Shew et al., 2021). As the leading developing country, China has taken blockchain technology as one of the cutting-edge strategic technologies in its informatization planning (The State Council of the People's Republic of China, 2016). Meanwhile, Chinese internet conglomerates, such as Alibaba, JD.com, and Baidu, have built their blockchain Software as a Service (SaaS) platform and launched different blockchain-based traceability programs (AliResearch, 2020). However, the application of blockchain-based traceability in the food supply chain is still in its early stage.

The future development of blockchain-based traceability technology in China's food supply chain requires more evidence from consumer markets. First, many companies hesitate to adopt this technology due to ambiguous market acceptance. By now, most studies have described the application potentials of blockchain-based traceability in the food supply chain in terms of technical superiority (Collart & Canales, 2021; Kshetri, 2018). However, only a few research focuses on the demand side to assess consumers' acceptance of blockchain-based traceable products (Lin et al., 2020; Shew et al., 2021). Second, Chinese food companies have adopted conventional traceability and/or certification for a long time (Calvin et al., 2006). It is unclear whether the introduction of blockchain-based traceability could bring higher profits and to what extent different types of quality assurance attributes are complementary or substitutable. However, few studies explore the relationship between them. Third, blockchain-based traceability is relatively new to consumers, most of whom have little knowledge of it. Existing studies suggest that improving consumers' knowledge and awareness might be helpful in improving their acceptance (Fan et al., 2020), but it has not been verified empirically. Lastly, although the heterogeneity analysis of the valuation by consumers' characteristics helps optimize marketing strategies, it has not been well studied.

To address these gaps, we aimed to explore the consumer acceptance of blockchain-based traceability in the tea supply chain in China. To meet this goal, we had four specific objectives. First, we investigated consumers' premiums to pay for blockchain-based traceability. Second, we compared the premiums for blockchain-based traceability with the other two most common quality assurance attributes—conventional traceability and certification. We further explored the relationship between blockchain-based traceability and certifications regarding consumers' valuation. Third, we designed a randomized information intervention to investigate the effect of exposure to the knowledge of blockchain on the premiums that consumers were willing to pay. Lastly, we examined the heterogeneity in valuations and heterogeneous treatment effects among different consumer groups.

In this study, we focused on the tea supply chain in China for three reasons. First, China, the leading tea producer, is also the largest tea consumption market in the world. Its tea consumption has increased from 1.82 million metric tons in 2015 to 2.45 million metric tons in 2020, accounting for over 40% of global consumption.[1] Second, the tea supply chain in China has been facing severe challenges in consumer trust in product quality and safety owing to excessive pesticide residues (Liu et al., 2015) and geographical origin fraud of tea products (Liu et al., 2019). Furthermore, decentralized production and fragmented supply chains put tremendous pressure on effectively supervising and regulating the industry. Lastly, existing measures to enhance tea consumers' trust appear deficient. The government-established quality certification system is widely used, where certification labels are printed on the package to indicate the elimination of corresponding quality problems (Liu et al., 2013; Nam et al., 2022). This straightforward signal, however, failed to win consumers' trust due to a series of food scandals during the past decade (Liu et al., 2019; Wang et al., 2020). Although China's Food Safety Law has stipulated the establishment of food traceability systems since 2015, no nationally unified and reliable traceability system has been implemented in the tea industry by now (Huang et al., 2022; Liu et al., 2015). Many Chinese consumers have a negative attitude towards those centralized traceability systems developed by local governments, large-scale private tea companies, or industry organizations (Liu et al., 2015). That is, there is a lack of trusted third parties to eliminate consumers' concerns about data authenticity. The application of blockchain-based traceability could be a promising solution to these issues.

The remainder of this paper is organized as follows. Section 2 introduces the methodology, including the sampling, experimental design, data collection, and empirical model. Section 3 reports the empirical results, and section 4 discusses the results. The last section concludes.

2. Methods

2.1. Sampling

Data used in this study was collected using an online tea consumer survey from October 26 to October 31, 2021. The survey was conducted in cooperation with *idiaoyan,* a professional data collection company.[2] The link to the questionnaire was sent to each target population through a mobile phone text message in six megacities located in different parts of China—Beijing, Shanghai, Shenzhen, Hangzhou, Zhengzhou, and Xi'an.[3] These megacities have a large consumer base and a GDP per capita far above the national average (see Table A1 in Appendix A). The population of the six megacities is a total of 84.2 million, accounting for 14.6% of China's urban population.

We selected megacities because they are the main target markets of traceable and certificated food in China at present. First, the establishment of China's food traceability system is still in the preliminary stage. The pilot programs usually start in megacities. For example, ten developed cities, including Shanghai, have been selected as the first batch of pilot cities for the Chinese meat and vegetables traceability system since 2010 (Ministry of Commerce of the People's Republic of China, 2010). Second, the uses of food traceability and certification are optional in China. It will be more profitable for companies to apply them in their high-quality and high-priced products. These products are usually sold in developed cities (Wang et al., 2020) because they are less likely to be affordable for consumers from small cities or rural areas. Some studies also verify a greater demand for food traceability and certification in urban China (Shimokawa et al., 2021; Yu et al., 2014).

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[1] Data source: The International Tea Committee (ITC).

[2] Details of this company are available at https://www.idiaoyan.com/desktop/index.

[3] We define megacities by their population. Specifically, according to the population census in 2020, China has seven super large-sized cities (more than 10 million population)—Beijing, Shanghai, Shenzhen, Chongqing, Guangzhou, Chengdu, and Tianjin, and 14 very-large cities (5–10 million population)—Wuhan, Dongguan, Xi'an, Hangzhou, Foshan, Nanjing, Shenyang, Qingdao, Jinan, Changsha, Harbin, Zhengzhou, Kunming, and Dalian. That is, there is a total of 21 megacities.

2.2. Intervention

We designed a randomized experiment to evaluate the impact of knowledge exposure on respondents' valuations of quality assurance attributes. To this end, we used two versions of questionnaires. One version was designed for the treatment group (hereafter referred to as the T version). The other was designed for the control group (hereafter referred to as the C version). The only difference between the two was that the T version included an introduction of blockchain technology and blockchain-based traceability before respondents were asked to offer their premiums. Specifically, we used an easily understood example, adapted from a popular video about how the blockchain works at Youtube.com, to illustrate the shared and distributed ledger system and to emphasize that the traceability information recorded in the blockchain was unforgeable and tamper-resistant (see Appendix A.1).[4] With these characteristics, blockchain-based traceability technology could ensure product quality and safety effectively.

To ensure that respondents fully understood the critical takeaway, we then asked respondents to identify the core feature of blockchain-based traceability from the three statements: *(1) Traceability information is more comprehensive; (2) Traceability information is unforgeable and tamper-proofing; (3) Traceability information is updated promptly*. Only respondents who chose the correct statement (i.e., the second one) were allowed to move into the premium part. Otherwise, s/he would be presented with the introduction and asked to identify the core feature of blockchain-based traceability again.

2.3. Data collection

The survey questionnaire included four sections. First, we collected each respondent's sociodemographic characteristics, including age, gender, educational attainment, personal monthly income, monthly household income per capita, and daily online time. Second, we collected information about each respondent's tea product consumption behaviors and preferences, such as whether s/he had bought tea products during the past year, the number of years of tea drinking, and the attributes of tea products s/he gives priority to. Third, we asked about each respondent's knowledge of blockchain-based traceability technology, including whether or not the respondent had heard of this technology and his/her self-rated knowledge level.

In the last section, we collected the respondents' premiums for different types of quality assurance attributes. We supposed that five types of tea products (Product A-E) were available, and all five products appeared similarly in an image of a 357-g Pu'er cake. The only difference among them was the traceability QR code and/or certification labels that were printed on the package. Specifically, Product A is the benchmark product; there was no other information except a commodity barcode, name, type (unfermented), and weight of the tea on the package. On the package of Product B, a QR code was printed to provide consumers with conventional centralized-technology-based traceable information. On the package of the Product C, a QR code was printed to provide consumers with the same but blockchain-based traceable information. On the package of Product D, three widely-used certification labels in the Chinese tea industry—the green food label, the organic agro-product label, and the agro-product geographical indications (Liu et al., 2019; Nam et al., 2022), were added to the benchmark product. Both certification labels and blockchain-based traceability QR codes were printed on the package of Product E. We explained traceability and certification labels briefly to ensure that all respondents in the treatment and control groups could understand what they meant.

To ensure the readability and understandability of the questions, we used two scenarios to solicit the premium respondents would be willing to pay. We presented Product A, B, and C in the first scenario. The benchmark product was priced at 300 CNY per 357 g, the average price in practice. Each respondent was required to present a percentage point ranging from 0 to 100 to indicate the premium they would like to pay for the conventionally traceable product and the blockchain-based traceable product, respectively, compared with the benchmark product. Product A, D, and E were presented to respondents in the second scenario. Similarly, each respondent was required to give their premiums for Product D and E, respectively. Fig. A1 in Appendix A shows how the five types of products were presented to respondents.

The link to the questionnaire was sent to 5000 targeted populations each day during the survey period. A total of 30,000 people received the message. Half received the T version, and half received the C version randomly. We uniformly distributed the link to the questionnaire in six cities each day. The average response rate was 13.4%, and 4017 people completed the survey. Thereinto, 2075 (51.7%) completed the T version, and 1942 (48.3%) completed the C version. Our sample was distributed evenly—666 (16.6%) in Beijing, 705 (17.6%) in Shanghai, 669 (16.6%) in Hangzhou, 756 (16.4%) in Shenzhen, 672 (16.1%) in Zhengzhou, and 648 (16.7%) in Xi'an. Table A2 in Appendix A shows the respondent rates on each date of sending.

2.4. Empirical model

We estimated the premiums respondents would be willing to pay for different quality assurance attributes and the impact of information intervention using the following regression model.

$$\begin{aligned} Y_{ij} = {} & \beta_0 + \beta_1 BCT_j + \beta_2 CT_j + \beta_3 CL_j + \beta_4 BCT_j \times CL_j + \beta_5 D_i + \beta_6 D_i \times BCT_j \\ & + \beta_7 D_i \times CT_j + \beta_8 D_i \times CL_j + \beta_9 D_i \times BCT_j \times CL_j + \alpha_i + \varepsilon_{ij} \end{aligned}$$

where Y_{ij} denotes the percentage points of the premium respondent i would be willing to pay for tea product j, ranging from 0 to 100. BCT_j, CT_j, and CL_j are indicators of quality assurance attributes of product j—blockchain-based traceability, conventional traceability, and certification labels, respectively. D_i is the treatment indicator, which equals one for respondents in the treatment group and zero for those in the control group. α_i is the individual fixed effect to control the individual-specific factors related to the premiums of respondent i.

β_0 measures the premium that respondent i in the control group would like to pay for the benchmark product without any traceability and certifications, which is set to be zero in our survey. The premiums that respondent i in the control group is willing to pay for blockchain-based traceability, conventional traceability, and certification labels of product j without any other quality assurance attributes are measured by β_1, β_2, and β_3, respectively. For the blockchain-based traceability of product j with certification labels, respondent i in the control group is willing to pay $\beta_1 + \beta_4$ percentage points. Similarly, respondent i is willing to pay a $\beta_3 + \beta_4$ percentage points premium for certifications labels of product j with blockchain-based traceability. The sign of β_4 reflects the complementarity or substitutability between blockchain-based traceability and certification labels. A positive sign of β_4 implies that blockchain-based traceability and certification labels are complements, because the premium that respondent i willing to pay for blockchain-based traceability (or certification labels) is amplified with the product with certification labels (or blockchain-based traceability). A negative sign means that these two attributes are substitutable.

β_5 measures the effect of information invention on consumers' premium for the benchmark product and thus equals zero. $\beta_6, \beta_7, \beta_8,$ and β_9 capture the causal effect of the blockchain information intervention on premiums of respondent i for blockchain-based traceability, conventional traceability, certification labels, and the combination of blockchain-based traceability and certificated labels of product j, respectively.

We first used an unweighted sample to estimate the coefficients.

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[4] The video is available online at https://www.youtube.com/watch?v=TVlo66aOZE0.

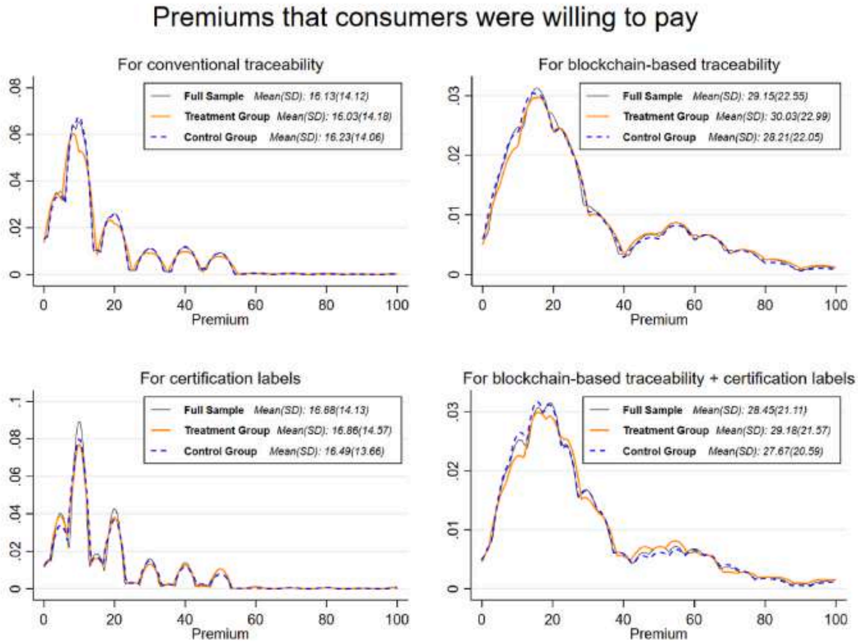

Fig. 1. The distribution of the premiums that consumers were willing to pay for quality assurance attributes.

Besides, it is very common that younger people are more likely to complete an online survey due to higher digital literacy (Lin et al., 2020). In consideration of the potential bias in the age distribution of the sample, we also used an age-weighted sample to estimate the coefficients. Specifically, we reweighted our sample to approximate the age distribution of the adult population in each of the corresponding sampling megacities.

To explore the heterogeneity in premiums that respondents were willing to pay and the effect of exposure to knowledge on premiums by respondent's characteristics, we re-run the regressions above by groups. We considered three types of characteristics of the respondent: (1) purchasing behaviors and preference, including whether the respondent had bought during the past year and the product attribute s/he prioritized—quality and safety, taste, green and organic attributes, price, or brand; (2) knowledge, i.e., whether the respondent had heard of blockchain-based traceability technology or not; and (3) respondent's sociodemographic indicators—age, education, and income. Referring to Cleary (1999), we used the bootstrap method to test the statistical significance of the difference between coefficients of regressions by groups.

3. Results

3.1. Descriptive statistics and balance test

Table 1 reports the descriptive statistics of the full sample. Half of our sample was males. On average, our sample was 33.36 years old. When we compared the age distribution of our unweighted sample with the adult population of the six megacities, we found that the unweighted sample was significantly younger (Column (1) and (3) in Table 2). In our sample, 31.17% were aged under 29, which was higher than the adult population of the six megacities (26.38%). 65.17% of our sample belonged to the range of 30–49. Only 3.66% was 50 or above, while 32.66% of the adult population in the selected megacities was 50 or above. When we reweighted our sample, the proportions of each age group were changed to 20.24%, 41.04%, and 38.72%, respectively (Column (2) in Table 2).

In addition, around 40% of individuals received undergraduate or postgraduate education, and nearly 90% had a personal monthly income of higher than 5000 CNY. Besides, 80% were tea drinkers, and their tea-drinking experience was around 6.46 years. Nearly 80% had bought tea last year. Of those tea buyers, 45% prioritized the taste of tea products, followed by quality and safety (35%). Only a few prioritized the green and organic attributes (8%), brand (6%), and price (6%). In addition, their knowledge of blockchain-based traceability technology was low. Only 38% had heard of this technology, and the average self-rated knowledge score was 2.50 out of 10.

Despite the randomness of the questionnaire delivery, the balance test showed significant differences in some aspects between the treatment group and the control group (Column (5) in Table 1). Specifically, individuals in the treatment group were more likely to have received undergraduate education (36% vs 32%), were less likely to expect growth in future income (75% vs 77%), and spent less time online (5.70 h vs 5.97 h) than their counterpart in the control group. More importantly, they were less likely to drink (78% vs 83%) and to buy tea (77% vs 81%). Even if they had bought, they were less likely to prioritize quality and safety (34% vs 37%) and more likely to prioritize the price of tea products (7% vs 4%) than those in the control group. To address the potential bias of our estimates caused by this unbalance, we used matching methods to reweight our sample to check the robustness of the analysis.

3.2. Premiums that consumers were willing to pay and treatment effects of information intervention

The distributions of premiums consumers were willing to pay for different quality assurance attributes are depicted graphically in Fig. 1. We drew the probability density function and reported the mean and standard deviation for the full sample, the treatment group, and the control group. It was noted that premiums tended to be multiple of 10, resulting in multi-peak patterns. This rounded measurement error is common in the data collection (Schneeweiss et al., 2010), and it would not threaten our results because the symmetric distribution does not change the mean, although it may cause a smaller standard deviation.

Table 3 presents consumers' premiums for different quality assurance attributes of tea products and the effect of the information intervention on consumers' premiums on average. Specifically, for the

Table 1
Descriptive statistics and balance test.

	Obs. (1)	Mean (S.D.)			
		Full Sample (2)	Treatment group (3)	Control group (4)	Diff. (5)= (3)–(4)
Age (yrs)	4017	33.36	33.36	33.36	−0.00
		(7.87)	(7.84)	(7.90)	(0.25)
Male (yes = 1)	4017	0.50	0.50	0.49	0.01
		(0.50)	(0.50)	(0.50)	(0.02)
Highest education level				***F-statistics: 1.59***	
Junior middle school or below	4017	0.01	0.01	0.01	−0.00
		(0.08)	(0.08)	(0.08)	(0.00)
General senior middle school	4017	0.02	0.02	0.02	−0.00
		(0.15)	(0.15)	(0.15)	(0.00)
Vocational senior middle school	4017	0.18	0.17	0.19	−0.01
		(0.38)	(0.38)	(0.39)	(0.01)
Junior college	4017	0.39	0.38	0.41	−0.03*
		(0.49)	(0.48)	(0.49)	(0.02)
Undergraduate education	4017	0.34	0.36	0.32	0.04***
		(0.48)	(0.48)	(0.47)	(0.01)
Postgraduate education	4017	0.05	0.06	0.05	0.00
		(0.23)	(0.23)	(0.23)	(0.01)
Household size (person)	4017	3.57	3.55	3.60	−0.05
		(1.07)	(1.06)	(1.08)	(0.03)
Monthly personal income (CNY)				***F-statistics: 0.26***	
$\leq$ *3000*	4017	0.07	0.07	0.07	0.00
		(0.26)	(0.26)	(0.25)	(0.01)
3000-5000	4017	0.06	0.05	0.06	−0.00
		(0.23)	(0.23)	(0.23)	(0.01)
5000-7000	4017	0.17	0.17	0.16	0.00
		(0.37)	(0.37)	(0.37)	(0.01)
7000- 9000	4017	0.29	0.29	0.28	0.01
		(0.45)	(0.45)	(0.45)	(0.01)
9000-11000	4017	0.23	0.23	0.23	−0.00
		(0.42)	(0.42)	(0.42)	(0.01)
$>$ *11000*	4017	0.19	0.19	0.19	−0.01
		(0.39)	(0.39)	(0.40)	(0.01)
Has an expectation of increased future income (yes = 1)	4017	0.76	0.75	0.77	−0.03**
		(0.43)	(0.44)	(0.42)	(0.01)
Daily time spent online (hrs)	4017	5.83	5.70	5.97	−0.27***
		(2.62)	(2.63)	(2.61)	(0.08)
Whether makes the habit of tea drinking (yes = 1)	4017	0.80	0.78	0.83	−0.05***
		(0.40)	(0.41)	(0.38)	(0.01)
Years of tea drinking (yrs)	4017	6.46	6.26	6.68	−0.42**
		(6.11)	(6.10)	(6.13)	(0.19)
Have bought tea during the past year (yes = 1)	4017	0.79	0.77	0.81	−0.05***
		(0.41)	(0.42)	(0.39)	(0.01)
When buying tea, the priority is [a]				***F-statistics: 4.08**** ***	
Quality and safety	3171	0.35	0.34	0.37	−0.03*
		(0.48)	(0.47)	(0.48)	(0.02)
Taste	3171	0.45	0.45	0.44	0.01
		(0.50)	(0.50)	(0.50)	(0.02)
Green and organic attributes	3171	0.08	0.08	0.08	0.00
		(0.28)	(0.28)	(0.28)	(0.01)
Price	3171	0.06	0.07	0.04	0.03***
		(0.23)	(0.26)	(0.20)	(0.01)
Brand	3171	0.06	0.06	0.06	−0.00
		(0.24)	(0.23)	(0.24)	(0.01)
Have heard of blockchain-based traceability technology	4017	0.38	0.37	0.38	−0.01
		(0.48)	(0.48)	(0.49)	(0.02)
Self-rated knowledge level of blockchain-based traceability technology (0-10) [b]	4017	2.50	2.48	2.53	−0.05
		(3.40)	(3.40)	(3.40)	(0.11)

Note: Significance level: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. *a*. Only respondents who had bought tea during the past year were asked about the attribute they prioritize. *b*. We defined the knowledge level of blockchain-based traceability technology who had never heard of it as zero.

unweighted sample, consumers in the control group were willing to pay a 28.2 percentage points premium for blockchain-based traceability, which was much higher than that for conventional traceability (16.2 percentage points) and certification labels (16.5 percentage points). However, the premium for blockchain-based traceability declined by 17.0 percentage points if the product had been labelled. The significantly negative sign of the coefficient of the interaction term (β_4), *with blockchain-based traceability × with certification labels*, implies that the blockchain-based traceability and certification labels were substitutable for consumers. Although the premium for the combination of two types of quality assurance attributes (27.7 percentage points) was statistically significantly higher than the premium for certification labels only, it was not statistically significantly different from the premium for blockchain-based traceability only. Hence, certification labels had no added value for blockchain-based traceable products for tea consumers.

We also found that information intervention significantly increased consumers' premiums for blockchain-based traceability. Specifically, the results indicated that exposure to the knowledge of blockchain and blockchain-based traceability technology increased consumers' premium for blockchain-based traceability by 1.8 percentage points. In other words, the information intervention increased the premium for blockchain-based traceability of an uncertificated product from 28.2 percentage points to 30.0 percentage points (i.e., an increase of 6.4 percent). It increased the premium for blockchain-based traceability of a certificated product from 27.7 percentage points to 29.5 percentage points (i.e., an increase of 6.5 percent). However, no significant effects were observed on premiums for conventional traceability and certification labels.

Column (2) in Table 3 reports the results from the age-weighted sample. The results showed a moderately lower premium (in percentage point) than that of the unweighted sample for quality-assurance attributes—blockchain-based traceability (26.4 vs 28.2), conventional traceability (14.7 vs 16.2), certification labels (13.7 vs 16.5), and the combination of blockchain-based traceability and certification labels

Table 2
Comparison of age distributions of the unweighted sample, the age-weighted sample and the adult population in six sampled megacities.

	(1)	(2)	(3)
	Unweighted sample *(%)*	Age-weighted sample *(%)*	Average adult population in the selected megacities *(%)* [a]
Age			
18–29	31.17	20.24	26.38
30–49	65.17	41.04	40.96
$\geq$ *50*	3.66	38.72	32.66

Note: a. The proportions of age are calculated using the data from the Beijing population census in 2020, the Shanghai population census in 2020, the Zhejiang population census in 2020, the Guangdong 1% population sample survey in 2015, the Shaanxi 1% population sample survey in 2015, and the Henan 1% population sample survey in 2015.

Table 3
The premiums (in percentage points) that consumers were willing to pay for tea traceability and certification labels, for the unweighted sample and the age-weighted sample.

	(1) Unweighted Sample	(2) Age-weighted Sample
Premium (relative to benchmark product)		
With blockchain-based traceability (β_1)	28.2***	26.4***
	(0.5)	(1.6)
With conventional traceability (β_2)	16.2***	14.7***
	(0.3)	(0.9)
With certification labels (β_3)	16.5***	13.7***
	(0.3)	(0.6)
With blockchain-based traceability × with certification labels (β_4)	−17.0***	−16.6***
	(0.4)	(1.5)
Treatment effects of the information intervention on premiums		
Treatment × with blockchain-based traceability (β_6)	1.8**	3.3
	(0.7)	(2.5)
Treatment × with conventional traceability (β_7)	−0.2	0.6
	(0.4)	(1.5)
Treatment × with certification labels (β_8)	0.4	1.6
	(0.4)	(1.2)
Treatment × with blockchain-based traceability × with certification labels (β_9)	−0.7	0.1
	(0.6)	(2.2)
$\beta_1 + \beta_3 + \beta_4$	27.7	23.5
Wald Test [F statistics]		
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_1$	[2.31]	[3.65*]
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_3$	[1556.96***]	[386.43***]
Observations	20,085	20,085
R-square	0.71	0.69

Note: Significance level: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Individual fixed effects are included. Standard errors are in parentheses. Standard errors are clustered at the respondent level. We did not report estimates of β_0 and β_1 because we set the premiums of the base group (the benchmark product) to zero.

(23.5 vs 27.7). The substitutability remained unchanged in the weighted sample. Besides, the effect of the information intervention on the premium for blockchain-based traceability was numerically larger but not statistically significant for the age-weighted sample (3.3 vs 1.8).

3.3. Heterogeneity in premiums and treatment effects across groups

First, we examined whether consumers' premiums and the treatment effects varied between tea consumers with purchasing experiences during the past year and those without it. As shown in the first two columns in Table 4, the consumers who had bought tea during the past year were willing to pay a higher premium for blockchain-based traceability than those who had not bought tea during the past year (29.7 vs 21.6). Similarly, they paid higher premiums for each quality assurance attribute—conventional traceability (17.2 vs 12.2), certification labels (16.9 vs 14.5), and the combination of blockchain-based traceability and certification labels (28.7 vs 22.9). A larger decline in the premium for blockchain-based traceability if the product was certificated was found among tea buyers than those non-tea buyers (−17.9 vs −13.2). Bootstrap tests suggested that these differences were statistically significant at a 1% level. We also found that exposure to blockchain knowledge could increase the premiums for blockchain-based traceability among both groups. Although the treatment effect was larger for non-tea buyers (2.9 versus 2.0), the difference was statistically insignificant.

Among tea buyers, we further analyzed the heterogeneity of premiums and treatment effects by their priorities for product attributes (Column (4) to (12) in Table 4). Of the five product attributes, the results indicated that tea consumers who prioritized quality and safety would like to pay a 28.2 percentage points premium for blockchain-based traceability, which was significantly lower than their counterparts. Tea buyers who prioritized price, green and organic attributes, brand, and taste were willing to pay the premium of 35.3, 31.7, 30.8, and 30.0 percentage points for blockchain-based traceability, respectively. For conventional traceability, certification labels, and the combination of blockchain-based traceability and certification labels, consumers who prioritized quality and safety paid the lowest premiums,16.6, 16.4, and 28.1, respectively. We only observed a statistically significant treatment effect among tea buyers who prioritized quality and safety the most. Specifically, the information intervention increased the premium for blockchain-based traceability by 4.1 percentage points, the premium for certification labels by 1.6 percentage points, and the premium for the combination of blockchain-based traceability and certification labels by 3.6 (=4.1 + 1.6–2.1) percentage points.

Then, we explored the heterogeneity in premiums and treatment effects between consumers who had never heard of blockchain-based traceability technology before and those who had heard of it. Table 5 reports the results. The former was willing to pay a slightly higher premium for quality assurance attributes. Specifically, consumers who had never heard of this technology would like to pay a premium of 28.5 percentage points for blockchain-based traceability, 16.4 percentage points for conventional traceability, and a 17.0 percentage points premium for certification labels. Their counterparts were willing to pay significantly lower premiums of 27.8, 15.9, and 15.6 percentage points, respectively. If the product had certification labels, the premiums of the two groups for blockchain-based traceability tend to decline substantially by 17.6 and 16.1 percentage points, respectively. The effect of information intervention was also significantly different for these two groups. Specifically, exposure to the knowledge of blockchain and blockchain-based traceability technology had no significant effect on consumers who had never heard of blockchain-based traceability. However, for consumers who had heard of this technology, exposure to knowledge significantly increased the premiums they would like to pay for blockchain-based traceability by 3.1 percentage points, while a substitution effect of 1.6 percentage points was found between blockchain-based traceability and certification labels. Besides, exposure to knowledge also increased the premium for certification labels by 1.4 percentage points.

Finally, we examined the heterogeneity in premiums and treatment effects by consumers' sociodemographic characteristics—age, education, and income. In terms of age, we compared consumers' premiums between those aged less than 50 and those aged 50 or above (Column (1)-(3), Table 6). We found that younger consumers were willing to pay a significantly higher premium (in percentage points) than older consumers for blockchain-based traceability (28.5 vs 19.6), conventional traceability (16.4 vs 11.1), certification labels (16.7 vs 11.3), and the combination of both blockchain-based traceability and certification labels (28.0 vs 19.3). Moreover, the information intervention could increase the premium of the younger group for blockchain-based traceability by 1.7 percentage points, while it was ineffective for older

Table 4
The premiums (in percentage points) that consumers were willing to pay for tea traceability and certification labels, by consumption behaviors and preferences.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Having bought tea or not in the past year			Conditional on having bought tea in the past year								
	No	Yes	Diff. =(1)–(2)	Prioritize quality and safety	Prioritize taste	Diff. = (4)–(5)	Prioritize green and organic attributes	Diff. = (4)–(7)	Prioritize price	Diff. = (4)–(9)	Prioritize brand	Diff. = (4)–(11)
Premium (relative to benchmark product)												
With blockchain-based traceability (β_1)	21.6***	29.7***	−8.1***	28.2***	30.0***	−1.8**	31.7***	−3.6***	35.3***	−7.1***	30.8***	−2.6***
	(1.0)	(0.6)		(0.9)	(0.9)		(2.0)		(3.2)		(2.3)	
With conventional traceability (β_2)	12.2***	17.2***	−4.9***	16.6***	17.3***	−0.7	17.2***	−0.6**	21.2***	−4.6***	16.7***	−0.1
	(0.6)	(0.4)		(0.6)	(0.5)		(1.2)		(2.1)		(1.3)	
With certification labels (β_3)	14.5***	16.9***	−2.4**	16.4***	17.1***	−0.7	18.0***	−1.6***	19.0***	−2.6***	16.4***	0.1
	(0.7)	(0.3)		(0.6)	(0.5)		(1.3)		(1.8)		(1.4)	
With blockchain-based traceability × with certification labels (β_4)	−13.2***	−17.9***	4.7***	−16.5***	−18.4***	1.9**	−18.7***	2.1***	−25.5***	−9.0***	−16.1***	−0.5
	(0.8)	(0.5)		(0.7)	(0.7)		(1.8)		(2.8)		(1.8)	
Treatment effects of the information intervention on premiums												
Treatment × with blockchain-based traceability (β_6)	2.9**	2.0**	1.0	4.1***	0.1	4.0***	4.3	−0.2	−1.2	5.3***	0.9	3.2***
	(1.4)	(0.8)		(1.3)	(1.2)		(3.0)		(4.0)		(3.4)	
Treatment × with conventional traceability (β_7)	0.9	−0.2	1.1	0.6	−1.2	1.8**	1.8	−1.2**	−3.0	3.6***	0.3	0.4
	(0.8)	(0.5)		(0.9)	(0.8)		(1.8)		(2.6)		(2.0)	
Treatment × with certification labels (β_8)	−0.9	0.9*	−1.8	1.6*	−0.1	1.7*	1.2	0.4	1.0	0.6*	2.2	−0.6*
	(0.8)	(0.5)		(0.9)	(0.7)		(1.9)		(2.5)		(2.3)	
Treatment × with blockchain-based traceability × with certification labels (β_9)	−1.0	−0.9	−0.2	−2.1*	0.5	−2.6**	−1.6	−0.5	2.7	−4.8***	−2.5	0.4
	(1.1)	(0.7)		(1.1)	(1.0)		(2.4)		(3.6)		(2.8)	
$\beta_1 + \beta_3 + \beta_4$	22.9	28.7	−5.9***	28.1	28.7	−0.7	31.0	−3.0***	28.8	−0.7**	31.1	−3.0***
Wald Test [F statistics]												
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_1$	[4.43**]	[5.29**]		[0.05]	[4.15**]		[0.14]		[6.76**]		[0.03]	
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_3$	[180.82**]	[1403.64***]		[491.91**]	[658.53***]		[183.02***]		[65.15***]		[63.66***]	
Observations	4230	15,855		5610	7065		1320		915		945	
R-square	0.70	0.71		0.71	0.71		0.71		0.70		0.71	

Note: Significance level: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Individual fixed effects are included. Standard errors are in parentheses. Standard errors are clustered at the respondent level.

Table 5

The premiums (in percentage points) that consumers were willing to pay for tea traceability and certification labels, by whether consumers had heard of blockchain-based traceability technology or not before the survey.

	(1)	(2)	(3)
	No	Yes	Diff. =(1)–(2)
Premium (relative to benchmark product)			
With blockchain-based traceability (β_1)	28.5***	27.8***	0.7*
	(0.7)	(0.8)	
With conventional traceability (β_2)	16.4***	15.9***	0.5*
	(0.4)	(0.5)	
With certification labels (β_3)	17.0***	15.6***	1.4***
	(0.4)	(0.5)	
With blockchain-based traceability × with certification labels (β_4)	−17.6***	−16.1***	−1.5***
	(0.6)	(0.6)	
Treatment effects of the information intervention on premiums			
Treatment × with blockchain-based traceability (β_6)	1.1	3.1***	−2.0***
	(0.9)	(1.1)	
Treatment × with conventional traceability (β_7)	−0.6	0.5	−1.1**
	(0.6)	(0.7)	
Treatment × with certification labels (β_8)	−0.3	1.4**	−1.7***
	(0.6)	(0.7)	
Treatment × with blockchain-based traceability × with certification labels (β_9)	−0.1	−1.6*	1.5**
	(0.8)	(0.9)	
$\beta_1 + \beta_3 + \beta_4$	27.9	27.3	0.6*
Wald Test [F statistics]			
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_1$	[1.63]	[0.70]	
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_3$	[874.89***]	[694.96***]	
Observations	12,520	7565	
R-square	0.70	0.72	

Note: Significance level: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Individual fixed effects are included. Standard errors are in parentheses. Standard errors are clustered at the respondent level.

consumers.

The comparison between the less-educated, whose highest education was a junior college or middle school education or lower and the highly educated, who received undergraduate or postgraduate education, is presented in Column (4)-(6) of Table 6. The valuations of quality assurance attributes were significantly lower among highly-educated consumers. Specifically, the less-educated group would like to pay a premium of 30.6 percentage points for blockchain-based traceability, 17.6 percentage points for conventional traceability, 17.6 percentage points for certification labels, and 29.2 percentage points for the combination of blockchain-based traceability and certification labels. Correspondingly, the highly educated would like to pay lower premiums by 6.3, 3.6, 2.8, and 3.8 percentage points, respectively. In addition, we only observed significant treatment effects on highly-educated consumers. Specifically, exposure to knowledge increased their premiums for blockchain-based traceability by 3.3 percentage points, 1.7 percentage points for certification labels, and 2.6 percentage points for the combination of blockchain-based traceability and certification labels.

When we looked at the heterogeneity between income groups, we also found the were statistically significant differences in most cases (Column (7)-(9) in Table 6). High-income consumers would like to pay higher premiums than their counterparts for blockchain-based traceability (29.3 vs 27.4), conventional traceability (16.6 vs 15.9), certification labels (16.7 vs 16.3), and the combination of both blockchain-based traceability and certification labels (28.4 vs 27.1). Moreover, information intervention resulted in a 2.5 percentage points increase in the premium for blockchain-based traceability for high-income consumers, while the treatment effect was not statistically significant for the lower-income group. Exposure to knowledge had no significant effects on the premiums that were paid for other quality assurance attributes for both groups.

3.4. Robustness analysis

Although we randomly assigned the information intervention, we still observed significant differences in several variables between the treatment and control groups. It could threaten the validity of our estimations. To account for this, we constructed a balanced sample by matching method and implemented the same regression analyses with the matched sample. Specifically, we used three matching methods: one nearest neighbor, radius, and kernel matching. The details on the matching are available in Appendix B. The three matching methods resulted in a balanced sample of 3,195, 4,011, and 4011 respondents, respectively. The results remained consistent with the findings of the unmatched sample, and they were reported in Appendix B (see Table B2-B9). In general, the premiums for quality assurance attributes were slightly lower if the matched sample was analyzed—blockchain-based traceability was in a range of 27.6–27.8 percentage points; the premium for conventional traceability was in a range of 15.9–16.1 percentage points; the premium for certification labels was in a range of 16.3–16.4 percentage points; the premium for the combination of blockchain-based traceability and certification labels was in a range of 27.2–27.4 percentage points. The effect of exposure to knowledge on the premium for blockchain-based traceability was slightly higher than that from an unmatched sample, ranging from 2.2 to 2.5 percentage points. The information intervention did not affect the premiums for other quality assurance attributes.

4. Discussion

We have tried to measure Chinese consumers' premiums for blockchain-based traceability of tea products compared to traditional quality assurance attributes. We found that consumers were willing to pay a 26.4 percentage points premium for blockchain-based traceability, which was higher than that for widely-applied quality assurance attributes —conventional traceability and certification labels, by 14.7 and 13.7 percentage points, respectively. The premiums for quality assurance attributes of our sample were lower than that of other studies. The high baseline price of the benchmark product in this study is a possible reason for the relatively lower premiums. For example, Yang et al. (2021) found that the premium of Chinese consumers for the Chinese organic certificated labels of Oolong tea products priced at 174.28 CNY/500g was 203%. The studies on other foods also conclude higher premiums for quality assurance attributes. Jin et al. (2017) found that Chinese consumers would be prepared to pay 34.3% and 44.5% premiums for apples priced at 6 CNY/500g with abbreviated and detailed conventional traceability information, respectively.

Meanwhile, we found that blockchain-based traceability and certification labels were substitutable. The presence of one quality assurance attribute decreases the premium consumers are willing to pay for the

Table 6

The premiums (in percentage points) that consumers were willing to pay for tea traceability and certification labels, by consumers' age, education, and income.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Age			Education			Income		
	Aged under 50	Aged 50 or over	Diff. =(1)–(2)	Junior college, or middle school or lower education	Undergraduate or postgraduate education	Diff. =(4)–(5)	Below the average [a]	Higher than the average	Diff. =(7)-(8)
Premium (relative to benchmark product)									
With blockchain-based traceability (β_1)	28.5***	19.6***	8.9***	30.6***	24.3***	6.3***	27.4***	29.3***	−1.9***
	(0.5)	(2.1)		(0.7)	(0.7)		(0.7)	(0.8)	
With conventional traceability (β_2)	16.4***	11.1***	5.3***	17.6***	14.0***	3.6***	15.9***	16.6***	−0.7**
	(0.3)	(1.2)		(0.4)	(0.4)		(0.4)	(0.5)	
With certification labels (β_3)	16.7***	11.3***	5.4***	17.6***	14.8***	2.8***	16.3***	16.7***	−0.4
	(0.3)	(1.1)		(0.4)	(0.4)		(0.4)	(0.5)	
With blockchain-based traceability × with certification labels (β_4)	−17.2***	−11.6***	−5.6***	−19.0***	−13.7***	−5.3***	−16.6***	−17.6***	−1.1**
	(0.4)	(2.0)		(0.6)	(0.7)		(0.4)	(2.0)	
Treatment effects of the information intervention on premiums									
Treatment × with blockchain-based traceability (β_6)	1.7**	4.2	−2.5***	1.2	3.3***	−2.1***	1.4	2.5**	−1.1*
	(0.7)	(3.3)		(1.0)	(1.0)		(0.9)	(1.1)	
Treatment × with conventional traceability (β_7)	−0.2	0.8	−1.0***	−0.8	1.0	−1.8***	0.1	−0.6	0.8*
	(0.5)	(1.9)		(0.6)	(0.6)		(0.6)	(0.7)	
Treatment × with certification labels (β_8)	0.4	0.9	−0.5***	−0.4	1.7***	−2.1***	0.0	0.9	−0.9*
	(0.5)	(1.7)		(0.6)	(0.6)		(0.6)	(0.7)	
Treatment × with blockchain-based traceability × with certification labels (β_9)	−0.7	−0.3	−0.4**	0.1	−2.4***	2.5***	−0.4	−1.1	0.7
	(0.6)	(2.7)		(0.8)	(0.8)		(0.8)	(1.0)	
$\beta_1 + \beta_3 + \beta_4$	28.0	19.3	8.7***	29.2	25.4	3.8***	27.1	28.4	−1.2***
Wald Test [F statistics]									
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_1$	[2.28]	[0.04]		[8.80***]	[5.03**]		[0.28]	[3.01*]	
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_3$	[1505.60***]	[64.44***]		[921.92***]	[660.48***]		[829.20***]	[731.46***]	
Observations	19,350	735		12,065	8020		11,610	8475	
R-square	0.71	0.69		0.70	0.72		0.71	0.71	

Note: Significance level: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Individual fixed effects are included. Standard errors are in parentheses. Standard errors are clustered at the respondent level. We used the mean of personal monthly income as the threshold, and respondents whose monthly income was higher than the mean value were defined as people with high person income. High household income per capita was constructed in the same way.

other one. Specifically, the introduction of blockchain-based traceability for certificated products resulted in an additional premium of 9.8 percentage points, which was considerably lower than that for uncertificated products, amounting to 26.4 percentage points. Moreover, the premium consumers would like to pay for the combination of blockchain-based traceability and certification labels was 23.5 percentage points, which was numerically lower than that for blockchain-based traceability only. This finding is enlightening for the choice of food quality assurance programs for stakeholders in the supply chain. From the perspective of companies' profit-maximizing, certification labels are redundant for a well-established blockchain-based traceability program, which could provide consumers with sufficient information on the quality and safety of the product.

We also investigated the heterogeneity in the premiums across consumers. First, we found that tea buyers paid higher premiums than non-tea buyers. Among tea buyers, those who prioritized prices paid higher than others. One possible explanation is that those price-sensitive consumers are more willing to pay for quality assurance attributes to be worth every penny. Second, consumers who had not heard of blockchain-based traceability were willing to pay a higher premium. We speculated that the high premium might come from the curiosity and admiration of consumers for the advanced new technology. Third, consumers who had a junior college, middle school, or lower education would like to pay significantly higher premiums than those who received undergraduate or postgraduate education. This result is consistent with earlier studies. For example, Jin et al. (2017) found that well-educated consumers paid a lower premium for added traceability information on apples. It is reasonable because consumers with undergraduate or postgraduate education are more capable of collecting information about the products, have more chances to access the market with high-quality products, and have a higher ability to identify high-quality products. Finally, the finding that young and high-income were willing to pay higher is also in line with the literature (Liu et al., 2015, 2020; Yu et al., 2014).

The randomized controlled trial suggests that information intervention could increase the premiums consumers would like to pay for blockchain-based traceability. Increasing the knowledge level did not result in a significant increase in the average premium for blockchain-based traceability in the age-weighted sample. However, the information invention increases the premium of particular groups. The heterogeneous analysis showed a larger effect on consumers who prioritized quality and safety (4.1 percentage points). This result is in accord with the wide-applied theories of technology adoption. In the technology acceptance model (TAM), perceived usefulness, defined as the degree to which a person believes that using a particular technology would enhance performance, is identified as a critical determinant of technology acceptance (Davis, 1989). The task-technology fit (TTF) model also emphasizes matching the technology's functionality to the task's demand (Dishaw & Strong, 1999). People who prioritize the quality and safety of the tea product are more likely to believe that blockchain-based traceability can satisfy their preferences and thereby pay a higher premium after receiving the information treatment, where the role of the technology in the assurance of quality and safety is highlighted.

The heterogeneity analysis also indicated that the effect of information intervention was only significant among consumers who had heard of blockchain-based traceability. One possible explanation is that the information in our intervention consolidates their beliefs about the unique advantage of the technology, while more is needed to make a difference to those who knew nothing. Besides, we found that the treatment effect was more significant for younger consumers with high education and income. It is consistent with the literature that wealthier people are more open to accepting new technologies due to better knowledge and ability to handle potential risks (Foster & Rosenzweig, 2010). Consumers with higher education should also be more able to require, assess and integrate information; thus, the intervention has a larger effect on them.

This study has potential limitations. First, our measurement of consumers' stated premiums based on the open-ended contingent valuation method might be biased, resulting from the hypothetical question (Mitchell & Carson, 2013). Although it is a good start, more advanced methods, such as the choice experiment (Louviere & Hensher, 1982; Louviere & Woodworth, 1983) and Becker-DeGroot-Marschak (BDM) auction (Becker et al., 1964), should be applied and compared in the future. Second, given the complexity of blockchain-based traceability technology, it might not be enough for consumers to fully understand it through a short textual explanation. In the future, new studies could explore whether other forms of information interventions, such as video, face-to-face explanation, and customer experience, will give rise to a larger impact. It is particularly important to test how the premiums respond to intervention tools when the sample is a less educated population. Lastly, the extrapolation of our findings should be cautious. Our findings are only applicable to consumers in megacities of China, which are the principal market of traceable and certificated food. In particular, the estimates from the unweighted sample provide an upper bound of the valuation and treatment effect.

5. Conclusion

Consumers attach increasing importance to food quality and safety with social and economic development. In comparison with traditional food assurance systems, blockchain technology provides a revolutionary solution to rebuild the confidence and trust of consumers due to its decentralization, transparency, and authenticity. The governments in many countries have given priority to developing it. However, the development of blockchain-based traceability is at an early stage. Consumers' acceptance of the technology is ambiguous, and thus enterprises might hesitate to invest owing to unclear profitability.

Our study suggested a substantial potential benefit of adopting blockchain-based traceability in tea products for companies. Using data from an online survey conducted in six megacities of China, we found that consumers valued blockchain-based traceability much more than the two widely-applied quality assurance attributes—conventional traceability and certification labels. Besides, blockchain-based traceability and certification labels were substitutable for consumers. These findings contribute to the enterprises' investment decisions on quality and safety assurance programs.

We also found that consumers' knowledge about blockchain-based traceability technology was limited, and exposure to knowledge produced a moderate effect. Although nearly eighty percent of respondents in our sample have received higher education, more than sixty percent of consumers had never heard of it, which is unsurprised considering the advancement and complexity of the technology. Our experiment suggested that the intervention of exposing consumers to more knowledge of blockchain and blockchain-based traceability significantly increased their premiums for blockchain-based traceability. It was particularly true for young consumers and those who prioritize tea quality and safety, receive undergraduate or postgraduate education, and have a high income. Given this, the knowledge about the advantages of blockchain-based traceability needs to be disseminated widely to accelerate the adoption and diffusion of this revolutionary quality assurance technology.

CRediT authorship contribution statement

Sihang Rao: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Fuqiao Chen:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Funding acquisition. **Wen Hu:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Feng Gao:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Jikun Huang:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Hongmei Yi:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Funding acquisition.

Declaration of competing interest

The authors declare that they have no conflict of interest that could inappropriately influence the work reported in this manuscript.

Data availability

Data will be made available on request.

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Appendices.

A. Experimental Design

A.1 Information intervention

The following is the introductory information additionally provided to the treatment group in the survey questionnaire.

"Blockchain is a tamper-proofing and unforgeable distributed ledger.

For example, there are two ways to the class fee bookkeeping procedures. The first one is that the class monitor takes the responsibility of collecting the class fee uniformly and recording the income and expenditure of each class fee. However, in this case, it is easy for the class monitor to embezzle the class fee and manipulate accounts. The second one is that each student participates in the bookkeeping, and any change in the class fee will be announced in the class, and then everyone will write down the change in their ledger after receiving the news. The latter way is a decentralized, distributed accounting method without third parties. Therefore, no one can embezzle the class fee unless he or she modifies more than 50% of the ledger of the class.

The blockchain-based traceability information of products is tamper-proofing and unforgeable, which can avoid shoddy products and ensure product quality and safety effectively. However, product information based on conventional traceability technology faces the risk of being tampered with, and it is difficult to ensure the authenticity of product information.

Table A1
The number of permanent residents and GDP per capita of six sampled cities in 2020.

	Number of permanent residents (million)	GDP per capita (CNY) [a]
Beijing	17.75	164,889
Shanghai	19.87	155,768
Shenzhen	17.56	159,309
Hangzhou	8.89	136,617
Zhengzhou	9.88	96,134
Xi'an	10.26	79,181

Note: Data source: China population census in 2020, China Statistical Yearbook (2021), Shenzhen Statistical Yearbook (2021), Hangzhou Statistical Yearbook (2021), Zhengzhou Statistical Yearbook (2021), Xi'an Statistical Yearbook (2021). a. The Chinese national GDP per capita is 72,000 CNY in 2020.

Table A2
Response rate and sample size.

Treatment group		Control group	
Date of sending	Response rate (%)	Date of sending	Response rate (%)
October 26	14.5 (724/5000)	October 28	12.0 (601/5000)
October 27	12.1 (607/5000)	October 29	12.4 (621/5000)
October 30	14.9 (744/5000)	October 31	14.4 (720/5000)
Total	13.8 (2075/15000)	Total	12.9 (1942/15000)

(a) Scenario 1

A: General tea product

B: Conventional traceable tea product

C: Blockchain-based traceable tea product

(b) Scenario 2

A: General tea product

D: certificated tea product

E: certificated and blockchain-based traceable tea product

Fig. A1. Five types of tea products..

B. Matching

To tackle the threat of the significant difference in characteristics between the treatment group and the control group on the validity of our estimations, we used the matching method to eliminate the unbalance and implemented the same regression analyses with the matched sample. Specifically, we used three types of matching methods—one nearest neighbor matching, radius matching, and kernel matching, respectively.

The variables used in the matching include age, gender, whether the respondent had received undergraduate or postgraduate education, household size, whether the respondent belonged to the high-income group, whether the respondent expected an increase in future income, daily time spent online, whether the respondent made the habit of tea drinking, whether the respondent had bought tea during the past year, the years of tea drinking, whether the respondent had heard of blockchain-based traceability technology, and the self-rated score of blockchain-based traceability technology knowledge.

Fig. B1shows the common support graphing. Table B1 reports the balance test for the matched sample.

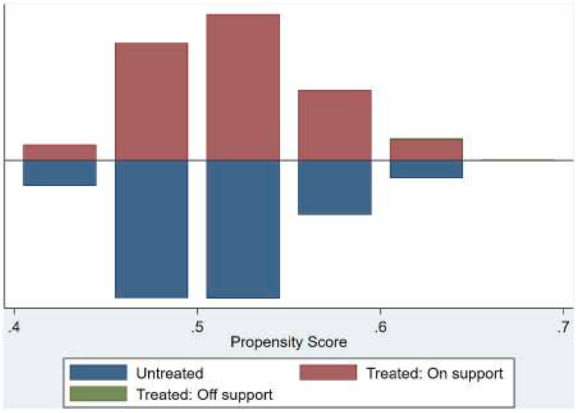

Fig. B1. Common support graphing.

Table B1
Balance test for the matched sample.

	One nearest-neighbor			Radius			Kernel		
	Treatment group	Control group	P-value	Treatment group	Control group	P-value	Treatment group	Control group	P-value
Age (yrs.)	33.36	33.63	0.28	33.36	33.39	0.91	33.36	33.30	0.82
Male (yes = 1)	0.50	0.49	0.71	0.50	0.50	0.93	0.50	0.50	0.98
Has received undergraduate or postgraduate education (yes = 1)	0.42	0.42	0.75	0.42	0.42	0.97	0.418	0.41	0.60
Household size (person)	3.55	3.59	0.21	3.55	3.55	0.90	3.55	3.56	0.71
High personal income (yes = 1)	0.42	0.42	0.95	0.42	0.42	0.98	0.42	0.42	0.87
Has an expectation of increased future income (yes = 1)	0.75	0.75	0.91	0.75	0.75	0.83	0.75	0.76	0.43
Daily time spent online (hrs.)	5.71	5.59	0.13	5.71	5.69	0.79	5.71	5.71	0.99
Whether makes the habit of tea drinking (yes = 1)	0.78	0.79	0.55	0.78	0.79	0.73	0.78	0.81	0.02**
Years of tea drinking (yrs.)	6.28	6.44	0.41	6.278	6.30	0.90	6.28	6.48	0.27
Have bought tea during the past year (yes = 1)	0.77	0.78	0.48	0.77	0.77	0.79	0.77	0.80	0.02**
Have heard of blockchain-based traceability technology	0.37	0.36	0.61	0.37	0.38	0.70	0.37	0.39	0.26
Self-rated knowledge level of blockchain-based traceability technology (0-10)	2.48	2.47	0.94	2.48	2.52	0.72	2.48	2.59	0.27

Note: Significance level: **$p < 0.05$.

Table B2

The premiums (in percentage points) that consumers were willing to pay for tea traceability and certification labels.

	(1) One nearest-neighbor	(2) Radius	(3) Kernel
Premium (relative to benchmark product)			
With blockchain-based traceability (β_1)	27.6***	27.6***	27.8***
	(0.8)	(0.5)	(0.5)
With conventional traceability (β_2)	16.1***	15.9***	16.0***
	(0.5)	(0.3)	(0.3)
With certification labels (β_3)	16.3***	16.3***	16.4***
	(0.5)	(0.3)	(0.3)
With blockchain-based traceability × with certification labels (β_4)	−16.7***	−16.6***	−16.8***
	(0.6)	(0.4)	(0.4)
Treatment effects of the information intervention on premiums			
Treatment × with blockchain-based traceability (β_6)	2.5***	2.5***	2.2***
	(0.9)	(0.7)	(0.7)
Treatment × with conventional traceability (β_7)	−0.1	0.2	0.0
	(0.6)	(0.4)	(0.4)
Treatment × with certification labels (β_8)	0.6	0.6	0.5
	(0.6)	(0.4)	(0.4)
Treatment × with blockchain-based traceability × with certification labels (β_9)	−1.0	−1.1*	−1.0
	(0.7)	(0.6)	(0.6)
$\beta_1 + \beta_3 + \beta_4$	27.2	27.3	27.4
Wald Test [F statistics]			
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_1$	[0.88]	[0.93]	[1.17]
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_3$	[597.05***]	[1451.56***	[1472.56***]
Observations	15,975	20,055	20,055
R-square	0.71	0.71	0.71

Note: Significance level: ***p < 0.01, **p < 0.05, *p < 0.1. Individual fixed effects are included. Standard errors in parentheses. Standard errors are clustered at the respondent level. The variables used in the matching includes age, gender, personal income, household income per capita, number of family members, the expectation of future income, education level, daily time spent online, whether the respondent made the habit of tea drinking, whether the respondent had bought tea during the past year, the years of tea drinking, whether the respondent had heard of blockchain-based traceability, and the self-rated score of blockchain-based traceability technology knowledge.

Table B3

The premiums (in percentage points) that consumers were willing to pay for tea traceability and certification labels, by consumption behaviors and preferences (One nearest-neighbor matching).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Having bought tea or not in the past year			Conditional on having bought tea in the past year								
	No	Yes	Diff. =(1)–(2)	Prioritize quality and safety	Prioritize taste	Diff. = (4)–(5)	Prioritize green and organic attributes	Diff. = (4)–(7)	Prioritize price	Diff. = (4)–(9)	Prioritize brand	Diff. = (4)–(11)
Premium (relative to benchmark product)												
With blockchain-based traceability (β_1)	22.1***	29.1***	−7.0***	26.8***	29.6***	−2.8**	29.6***	−2.8***	38.8***	−12.0***	32.5***	−5.7***
	(1.6)	(0.9)		(1.3)	(1.3)		(3.0)		(4.2)		(3.7)	
With conventional traceability (β_2)	13.3***	16.9***	−3.6**	15.9***	16.9***	−1.0	18.0***	−2.1**	23.7***	−7.7***	16.7***	−0.8
	(1.0)	(0.6)		(0.8)	(0.8)		(2.2)		(3.1)		(2.0)	
With certification labels (β_3)	16.0***	16.3***	−0.4	15.8***	15.6***	0.2	18.6***	−2.7***	22.6***	−6.8***	17.1***	−1.3*
	(1.1)	(0.5)		(0.8)	(0.7)		(2.3)		(3.0)		(2.1)	
With blockchain-based traceability × with certification labels (β_4)	−13.8*** (1.1)	−17.5*** (0.7)	3.7*	−16.1*** (1.0)	−18.0*** (1.1)	1.9	−18.6*** (2.7)	2.5**	−26.9*** (3.4)	10.9***	−14.8*** (2.3)	−1.3
Treatment effects of the information intervention on premiums												
Treatment × with blockchain-based traceability (β_6)	2.5 (1.8)	2.6** (1.0)	−0.1	5.4*** (1.6)	0.5 (1.6)	5.0***	6.4* (3.7)	−1.0	−4.6 (4.8)	10.1***	−0.9 (4.5)	6.3***
Treatment × with conventional traceability (β_7)	−0.2 (1.2)	0.0 (0.7)	−0.2	1.3 (1.1)	−0.8 (1.0)	2.1*	1.0 (2.6)	0.3	−5.5 (3.5)	6.8***	0.3 (2.5)	1.1
Treatment × with certification labels (β_8)	−2.3*	1.5**	−3.8*	2.2**	1.4*	0.8	0.6	1.6*	−2.6	4.9***	1.5	0.7
	(1.2)	(0.6)		(1.0)	(0.8)		(2.6)		(3.5)		(2.8)	
Treatment × with blockchain-based traceability × with certification labels (β_9)	−0.5 (1.3)	−1.2 (0.9)	0.7	−2.6* (1.4)	0.1 (1.3)	−2.7	−1.7 (3.1)	−0.9	4.1 (4.0)	−6.7***	−3.8 (3.2)	1.2
$\beta_1 + \beta_3 + \beta_4$	24.2	27.9	−3.8*	26.6	27.2	−0.6	29.5	−3.0***	34.5	−7.9***	34.8	−8.2***
Wald Test [F statistics]												
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_1$	[8.01***]	[4.19**]		[0.12]	[5.67**]		[0.00]		[2.82*]		[0.98]	
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_3$	[69.82***]	[544.99***]		[199.18***]	[255.43***]		[92.65***]		[23.40***]		[27.82***]	
Observations	3575	12,400		4350	5490		1045		785		730	
R-square	0.72	0.71		0.72	0.71		0.73		0.71		0.70	

Note: Significance level: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Individual fixed effects are included. Standard errors are in parentheses. Standard errors are clustered at the respondent level.

Table B4

The premiums (in percentage points) that consumers were willing to pay for tea traceability and certification labels, by consumption behaviors and preferences (Radius matching).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Having bought tea or not in the past year			Conditional on having bought tea in the past year								
	No	Yes	Diff. =(1)–(2)	Prioritize quality and safety	Prioritize taste	Diff. = (4)–(5)	Prioritize green and organic attributes	Diff. = (4)–(7)	Prioritize price	Diff. = (4)–(9)	Prioritize brand	Diff. = (4)–(11)
Premium (relative to benchmark product)												
With blockchain-based traceability (β_1)	21.6***	29.3***	−7.7***	27.8***	29.6***	−1.8	31.2***	−3.3***	35.0***	−7.2***	29.9***	−2.1***
	(1.0)	(0.6)		(0.9)	(0.8)		(2.0)		(3.2)		(2.4)	
With conventional traceability (β_2)	12.2***	16.9***	−4.7***	16.5***	17.1***	−0.7	16.8***	−0.3	21.1***	−4.7***	15.9***	0.6**
	(0.6)	(0.4)		(0.6)	(0.5)		(1.2)		(2.1)		(1.3)	
With certification labels (β_3)	14.6***	16.8***	−2.3**	16.3***	17.0***	−0.7	17.5***	−1.2***	19.2***	−2.9***	16.0***	0.3
	(0.7)	(0.3)		(0.6)	(0.5)		(1.2)		(1.9)		(1.5)	
With blockchain-based traceability × with certification labels (β_4)	−13.2***	−17.6***	4.4***	−16.3***	−18.2***	1.8	−18.3***	2.0***	−25.2***	8.9***	−15.4***	−0.9**
	(0.8)	(0.5)		(0.7)	(0.7)		(1.8)		(2.8)		(1.8)	
Treatment effects of the information intervention on premiums												
Treatment × with blockchain-based traceability (β_6)	2.9**	2.4***	0.5	4.5***	0.5	4.0	4.9*	−0.4	−0.8	5.3***	1.7	2.8***
	(1.4)	(0.8)		(1.3)	(1.2)		(2.9)		(4.0)		(3.4)	
Treatment × with conventional traceability (β_7)	0.9	−0.0	0.9	0.8	−1.0	1.8	2.2	−1.4***	−3.0	3.8***	1.1	−0.3
	(0.8)	(0.5)		(0.9)	(0.7)		(1.7)		(2.6)		(2.0)	
Treatment × with certification labels (β_8)	−0.9	1.0**	−1.9	1.7**	0.0	1.7	1.6	0.1	0.8	0.9**	2.6	−0.9**
	(0.8)	(0.5)		(0.9)	(0.8)		(1.8)		(2.5)		(2.3)	
Treatment × with blockchain-based traceability × with certification labels (β_9)	−1.1	−1.1	0.1	−2.4**	0.3	−2.6	−2.0	−0.4	2.4	−4.8***	−3.1	0.8
	(1.1)	(0.7)		(1.1)	(1.0)		(2.4)		(3.5)		(2.8)	
$\beta_1 + \beta_3 + \beta_4$	23.0	28.5	−5.6***	27.8	28.4	−0.6	30.4	−2.6***	29.0	−1.1***	30.4	−2.6***
Wald Test [F statistics]												
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_1$	[5.16**]	[4.06**]		[0.00]	[3.36*]		[0.19]		[6.67**]		[0.11]	
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_3$	[168.85***]	[1362.25***]		[496.89***]	[632.40***]		[185.23***]		[59.14***]		[55.73***]	
Observations	4200	15,855		5610	7065		1320		915		945	
R-square	0.70	0.71		0.71	0.71		0.71		0.70		0.71	

Note: Significance level: ***p < 0.01, **p < 0.05, *p < 0.1. Individual fixed effects are included. Standard errors are in parentheses. Standard errors are clustered at the respondent level.

Table B5
The premiums (in percentage points) that consumers were willing to pay for tea traceability and certification labels, by consumption behaviors and preferences (Kernel matching).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Having bought tea or not in the past year			Conditional on having bought tea in the past year								
	No	Yes	Diff. =(1)–(2)	Prioritize quality and safety	Prioritize taste	Diff. = (4)–(5)	Prioritize green and organic attributes	Diff. = (4)–(7)	Prioritize price	Diff. = (4)–(9)	Prioritize brand	Diff. = (4)–(11)
Premium (relative to benchmark product)												
With blockchain-based traceability (β_1)	21.8***	29.4***	−7.3***	27.8***	29.7***	−1.8**	31.2***	−3.4***	35.1***	−7.3***	29.9***	−2.1***
	(1.1)	(0.6)		(0.9)	(0.9)		(2.0)		(3.2)		(2.3)	
With conventional traceability (β_2)	12.3***	17.0***	−4.6***	16.5***	17.1***	−0.6	16.8***	−0.3	21.3***	−4.8***	16.0***	0.5**
	(0.6)	(0.4)		(0.6)	(0.5)		(1.2)		(2.2)		(1.3)	
With certification labels (β_3)	14.6***	16.8***	−2.2**	16.4***	17.0***	−0.6	17.4***	−1.0***	19.3***	−2.9***	16.2***	0.2
	(0.7)	(0.4)		(0.6)	(0.5)		(1.2)		(1.9)		(1.5)	
With blockchain-based traceability × with certification labels (β_4)	−13.3***	−17.6***	4.3***	−16.3***	−18.2***	2.0**	−18.3***	2.0***	−25.3***	9.1***	−15.1***	−1.1***
	(0.8)	(0.5)		(0.7)	(0.7)		(1.7)		(2.8)		(1.8)	
Treatment effects of the information intervention on premiums												
Treatment × with blockchain-based traceability (β_6)	2.8*	2.3***	0.4	4.4***	0.4	4.0***	4.8	−0.3	−1.0	5.4***	1.7	2.8***
	(1.4)	(0.8)		(1.3)	(1.2)		(2.9)		(4.0)		(3.4)	
Treatment × with conventional traceability (β_7)	0.8	−0.0	0.8	0.7	−1.0	1.8**	2.2	−1.5***	−3.1	3.8***	1.0	−0.2
	(0.8)	(0.5)		(0.9)	(0.7)		(1.7)		(2.6)		(2.0)	
Treatment × with certification labels (β_8)	−0.9	1.0*	−1.9	1.6*	0.1	1.6*	1.8	−0.1	0.7	0.9**	2.4	−0.8*
	(0.9)	(0.5)		(0.9)	(0.8)		(1.8)		(2.5)		(2.3)	
Treatment × with blockchain-based traceability × with certification labels (β_9)	−0.9	−1.1	0.2	−2.4**	0.3	−2.7**	−2.0	−0.4	2.5	−4.9***	−3.4	1.0*
	(1.1)	(0.7)		(1.1)	(1.0)		(2.4)		(3.5)		(2.8)	
$\beta_1 + \beta_3 + \beta_4$	23.1	28.6	−5.5***	28.0	28.4	−0.4	30.4	−2.4***	29.1	−1.1***	31.0	−3.0***
Wald Test [F statistics]												
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_1$	[4.16**]	[3.73*]		[0.05]	[3.93**]		[0.24]		[6.63**]		[0.39]	
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_3$	[167.97***]	[1347.25***]		[495.75***]	[627.64***]		[178.33***]		[59.53***]		[53.58***]	
Observations	4200	15,855		5610	7065		1320		915		945	
R-square	0.70	0.71		0.71	0.71		0.71		0.70		0.71	

Note: Significance level: ***p < 0.01, **p < 0.05, *p < 0.1. Individual fixed effects are included. Standard errors are in parentheses. Standard errors are clustered at the respondent level.

Table B6

The premiums (in percentage points) that consumers were willing to pay for tea traceability and certification labels, by whether the respondent had heard of blockchain-based traceability technology or not.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	One nearest neighbor			Radius			Kernel		
	No	Yes	Diff. =(1)–(2)	No	Yes	Diff. =(4)–(5)	No	Yes	Diff. =(7)–(8)
Premium (relative to benchmark product)									
With blockchain-based traceability (β_1)	27.2***	28.2***	−1.0	27.6***	27.5***	0.0	28.0***	27.6***	0.4
	(1.0)	(1.2)		(0.7)	(0.8)		(0.7)	(0.8)	
With conventional traceability (β_2)	15.9***	16.4***	−0.5	15.8***	15.9***	−0.0	16.1***	15.9***	0.1
	(0.6)	(0.8)		(0.4)	(0.5)		(0.4)	(0.5)	
With certification labels (β_3)	16.3***	16.1***	−0.2	16.6***	15.7***	0.9***	16.8***	15.7***	1.1***
	(0.6)	(0.8)		(0.4)	(0.5)		(0.4)	(0.5)	
With blockchain-based traceability × with certification labels (β_4)	−16.5***	−17.0***	−0.5	−17.0***	−16.0***	−1.0**	−17.3***	−16.0***	−1.3***
	(0.8)	(1.0)		(0.5)	(0.6)		(0.6)	(0.6)	
Treatment effects of the information intervention on premiums									
Treatment × with blockchain-based traceability (β_6)	2.4**	2.7*	−0.3	2.0**	3.3***	−1.3**	1.6*	3.2***	−1.6***
	(1.2)	(1.4)		(0.9)	(1.1)		(0.9)	(1.1)	
Treatment × with conventional traceability (β_7)	−0.1	−0.0	−0.1	−0.0	0.5	−0.6	−0.3	0.5	−0.8*
	(0.7)	(0.9)		(0.6)	(0.7)		(0.6)	(0.7)	
Treatment × with certification labels (β_8)	0.4	1.0	−0.5	0.1	1.4*	−1.2***	−0.1	1.4*	−1.4***
	(0.7)	(0.9)		(0.6)	(0.7)		(0.6)	(0.7)	
Treatment × with blockchain-based traceability × with certification labels (β_9)	−1.2	−0.7	−0.5	−0.7	−1.8*	1.1*	−0.4	−1.8*	1.4**
	(0.9)	(1.2)		(0.8)	(0.9)		(0.8)	(0.9)	
$\beta_1 + \beta_3 + \beta_4$	27.0	27.3	−0.2	27.2	27.2	−0.1	27.5	27.4	0.1
Wald Test [F statistics]									
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_1$	[0.09]	[1.47]		[0.73]	[0.22]		[1.05]	[0.20]	
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_3$	[322.90***]	[302.27***]		[806.33***]	[663.05***]		[824.92***]	[655.84***]	
Observations	10,075	5900		12,500	7555		12,500	7555	
R-square	0.71	0.72		0.70	0.72		0.70	0.72	

Note: Significance level: ***p < 0.01, **p < 0.05, *p < 0.1. Individual fixed effects are included. Standard errors are in parentheses. Standard errors are clustered at the respondent level.

Table B7

The premiums (in percentage points) that consumers were willing to pay for tea traceability and certification labels, by age.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	One nearest neighbor			Radius			Kernel		
	Aged under 50	Aged 50 or over	Diff. =(1)–(2)	Aged under 50	Aged 50 or over	Diff. =(4)–(5)	Aged under 50	Aged 50 or over	Diff. =(7)–(8)
Premium (relative to benchmark product)									
With blockchain-based traceability (β_1)	27.8***	20.8***	7.0***	27.9***	19.2***	8.7***	28.1***	19.3***	8.8***
	(0.8)	(2.9)		(0.5)	(2.3)		(0.5)	(2.3)	
With conventional traceability (β_2)	16.3***	12.0***	4.3***	16.0***	10.8***	5.3***	16.2***	10.7***	5.5***
	(0.5)	(1.8)		(0.3)	(1.2)		(0.3)	(1.2)	
With certification labels (β_3)	16.4***	11.8***	4.6***	16.5***	11.2***	5.2***	16.6***	11.1***	5.5***
	(0.5)	(1.7)		(0.3)	(1.3)		(0.3)	(1.2)	
With blockchain-based traceability × with certification labels (β_4)	−16.8***	−13.3***	−3.6***	−16.8***	−11.3***	−5.5***	−16.9***	−11.3***	−5.6***
	(0.6)	(2.6)		(0.4)	(2.3)		(0.4)	(2.3)	
Treatment effects of the information intervention on premiums									
Treatment × with blockchain-based traceability (β_6)	2.5***	3.0	−0.5	2.4***	4.7	−2.2***	2.2***	4.6	−2.4***
	(0.9)	(3.8)		(0.7)	(3.4)		(0.7)	(3.4)	
Treatment × with conventional traceability (β_7)	−0.1	−0.1	−0.0	0.2	1.2	−1.0***	−0.0	1.3	−1.4***
	(0.6)	(2.3)		(0.5)	(1.9)		(0.5)	(1.9)	
Treatment × with certification labels (β_8)	0.6	0.3	0.3	0.6	0.9	−0.3***	0.5	1.1	−0.6***
	(0.6)	(2.2)		(0.5)	(1.9)		(0.5)	(1.8)	
Treatment × with blockchain-based traceability × with certification labels (β_9)	−1.1	1.3	−2.4***	−1.1*	−0.6	−0.5***	−1.0*	−0.6	−0.4**
	(0.8)	(3.2)		(0.6)	(2.9)		(0.6)	(2.9)	
$\beta_1 + \beta_3 + \beta_4$	27.4	19.3	8.0***	27.5	19.1	8.4***	27.7	19.0	8.7***
Wald Test [F statistics]									
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_1$	[0.70]	[0.55]		[0.94]	[0.00]		[1.17]	[0.01]	
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_3$	[573.28***]	[58.10***]		[1407.28***]	[52.60***]		[1426.70]	[60.20***]	

(*continued on next page*)

Table B7 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	One nearest neighbor			Radius			Kernel		
	Aged under 50	Aged 50 or over	Diff. =(1)–(2)	Aged under 50	Aged 50 or over	Diff. =(4)–(5)	Aged under 50	Aged 50 or over	Diff. =(7)–(8)
Observations	15,375	600		19,320	735		19,320	735	
R-square	0.71	0.70		0.71	0.69		0.71	0.69	

Note: Significance level: ***p < 0.01, **p < 0.05, *p < 0.1. Individual fixed effects are included. Standard errors are in parentheses. Standard errors are clustered at the respondent level. We used the mean of personal monthly income as the threshold, and people whose monthly income was higher than the mean value were defined as people with high-income levels.

Table B8

The premiums (in percentage points) that consumers were willing to pay for tea traceability and certification labels, by education level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	One nearest neighbor			Radius			Kernel		
	Junior college, or middle school or lower education	Undergraduate or postgraduate education	Diff.= (1)–(2)	Junior college, or middle school or lower education	Undergraduate or postgraduate education	Diff.= (4)-(5)	Junior college, or middle school or lower education	Undergraduate or postgraduate education	Diff.= (7)-(8)
Premium (relative to benchmark product)									
With blockchain-based traceability (β_1)	29.5*** (1.1)	24.9*** (1.0)	4.6***	30.2*** (0.7)	23.9*** (0.7)	6.3***	30.3*** (0.7)	24.4*** (0.7)	5.9***
With conventional traceability (β_2)	16.9*** (0.7)	15.0*** (0.7)	1.9**	17.3*** (0.4)	13.8*** (0.4)	3.6***	17.4*** (0.4)	14.0*** (0.4)	3.4***
With certification labels (β_3)	17.1*** (0.6)	15.1*** (0.6)	1.9***	17.5*** (0.4)	14.7*** (0.4)	2.8***	17.5*** (0.4)	14.8*** (0.4)	2.7***
With blockchain-based traceability × with certification labels (β_4)	−18.2*** (0.9)	−14.7*** (0.8)	−3.4***	−18.8*** (0.6)	−13.7*** (0.5)	−5.1***	−18.8*** (0.6)	−13.8*** (0.5)	−5.0***
Treatment effects of the information intervention on premiums									
Treatment × with blockchain-based traceability (β_6)	2.3* (1.3)	2.7** (1.2)	−0.4	1.6 (1.0)	3.7*** (1.0)	−2.1***	1.5 (1.0)	3.3*** (1.0)	−1.7***
Treatment × with conventional traceability (β_7)	−0.1 (0.8)	−0.0 (0.8)	−0.1	−0.5 (0.6)	1.2* (0.6)	−1.7***	−0.6 (0.6)	1.0 (0.6)	−1.6***
Treatment × with certification labels (β_8)	0.1 (0.8)	1.3* (0.8)	−1.2	−0.3 (0.6)	1.8*** (0.6)	−2.1***	−0.3 (0.6)	1.7*** (0.6)	−2.0***
Treatment × with blockchain-based traceability × with certification labels (β_9)	−0.7 (1.0)	−1.4 (1.0)	0.6	−0.1 (0.8)	−2.5*** (0.8)	2.3***	−0.1 (0.8)	−2.3*** (0.8)	2.3***
$\beta_1 + \beta_3 + \beta_4$	28.4	25.3	3.1***	28.9	25.0	3.9***	29.0	25.4	3.6***
Wald Test [F statistics]									
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_1$	[2.28]	[0.47]		[7.01***]	[5.60**]		[7.14***]	[4.77**]	
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_3$	[316.68***]	[301.30***]		[799.24***]	[681.72***]		[838.09***]	[646.37***]	
Observations	9360	6615		12,065	7990		12,065	7990	
R-square	0.71	0.72		0.70	0.72		0.70	0.72	

Note: Significance level: ***p < 0.01, **p < 0.05, *p < 0.1. Individual fixed effects are included. Standard errors are in parentheses. Standard errors are clustered at the respondent level.

Table B9

The premiums (in percentage points) that consumers were willing to pay for tea traceability and certification labels, by income level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	One nearest neighbor			Radius			Kernel		
	Below the average	Higher than the average	Diff. =(1)–(2)	Below the average	Higher than the average	Diff. =(4)–(5)	Below the average	Higher than the average	Diff. =(7)–(8)
Premium (relative to benchmark product)									
With blockchain-based traceability (β_1)	26.8***	28.7***	−2.0**	26.9***	28.5***	−1.6***	27.2***	28.7***	−1.6***
	(1.0)	(1.1)		(0.7)	(0.8)		(0.7)	(0.8)	
With conventional traceability (β_2)	15.6***	16.8***	−1.1*	15.6***	16.3***	−0.7**	15.8***	16.4***	−0.6*
	(0.6)	(0.8)		(0.4)	(0.5)		(0.4)	(0.5)	
With certification labels (β_3)	16.1***	16.4***	−0.3	16.2***	16.4***	−0.2	16.3***	16.5***	−0.2
	(0.6)	(0.7)		(0.4)	(0.5)		(0.4)	(0.5)	
With blockchain-based traceability × with certification labels (β_4)	−16.3***	−17.2***	0.9	−16.3***	−17.1***	0.8*	−16.4***	−17.2***	0.8*
	(0.8)	(0.9)		(0.5)	(0.6)		(0.6)	(0.6)	
Treatment effects of the information intervention on premiums									
Treatment × with blockchain-based traceability (β_6)	2.1*	3.1**	−1.0	1.9**	3.3***	−1.4**	1.6*	3.0***	−1.4**
	(1.2)	(1.4)		(0.9)	(1.1)		(0.9)	(1.1)	
Treatment × with conventional traceability (β_7)	0.4	−0.7	1.1	0.5	−0.2	0.7	0.3	−0.3	0.6
	(0.8)	(0.9)		(0.6)	(0.7)		(0.6)	(0.7)	
Treatment × with certification labels (β_8)	0.2	1.2	−0.9	0.2	1.2*	−1.0**	0.0	1.1	−1.1**
	(0.7)	(0.9)		(0.6)	(0.7)		(0.6)	(0.7)	
Treatment × with blockchain-based traceability × with certification labels (β_9)	−0.7	−1.5	0.8	−0.7	−1.6*	0.9	−0.6	−1.5	0.9
	(1.0)	(1.2)		(0.8)	(0.9)		(0.8)	(0.9)	
$\beta_1 + \beta_3 + \beta_4$	26.5	27.9	−1.4*	26.8	27.8	−1.0**	27.1	28.0	−0.9**
Wald Test [F statistics]									
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_1$	[0.12]	1.08]		[0.03]	[1.76]		[0.05]	[2.13]	
$H_0 : \beta_1 + \beta_3 + \beta_4 = \beta_3$	[336.53***]	260.61***]		[741.44***]	[733.70***]		[777.04***]	[705.13***]	
Observations	9295	6680		11,585	8470		11,585	8470	
R-square	0.71	0.71		0.71	0.71		0.71	0.71	

Note: Significance level: ***p < 0.01, **p < 0.05, *p < 0.1. Individual fixed effects are included. Standard errors are in parentheses. Standard errors are clustered at the respondent level. We used the mean of personal monthly income as the threshold, and people whose monthly income was higher than the mean value were defined as people with high-income levels.

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