Received: 15 October 2019 | Accepted: 27 August 2020

DOI: 10.1002/aepp.13135

FEATURED ARTICLE

# Blockchain-based traceability and demand for U.S. beef in China

**Wen Lin**[1] | **David L. Ortega**[1,2] | **Danielle Ufer**[2] | **Vincenzina Caputo**[2] | **Titus Awokuse**[2]

[1]China Academy for Rural Development (CARD), School of Public Affairs, Zhejiang University, Hangzhou, China

[2]Department of Agricultural, Food and Resource Economics, Michigan State University, East Lansing, Michigan, USA

**Correspondence**
David L. Ortega, Department of Agricultural, Food and Resource Economics, Michigan State University, East Lansing, MI, USA.
Email: dlortega@msu.edu

**Funding information**
Michigan State University's AgBioResearch; USDA National Institute of Food and Agriculture, Grant/Award Number: Hatch project 04189

**Editor in charge:** Daniel Petrolia

**Abstract**

Amid stringent traceability requirements and a nearly 14-year ban, the U.S. beef industry is rebuilding its market presence in China. Blockchain technology offers a responsive means of meeting Chinese import traceability requirements while also addressing consumers' food safety concerns. We evaluate Chinese demand for U.S. beef and blockchain-based traceability and find that a sizeable segment of the market (37%) is willing to pay a premium for U.S. beef that is traceable using blockchains. Results indicate that investments in traceability systems that utilize blockchain technology may be an effective way for producers to capture a significant market share in China.

**KEYWORDS**

blockchain, Chinese consumers, country of origin, traceability, U.S. beef demand

**JEL CLASSIFICATION**

Q13; Q17

## INTRODUCTION

Current price volatility and stagnant per capita consumption in the U.S. has increased the importance of identifying alternative markets for the beef industry to remain profitable. China's increasingly affluent consumer base of 1.4 billion people presents lucrative market opportunities for U.S. agricultural products. Beef, historically a less-sought-out protein, is now the fastest-growing meat consumed in China, surpassing the demand growth of more widely eaten meats like pork (Liu et al., 2009).

Beef consumption in China increased by 22.3%, from 6.45 million tons in 2011 to 7.89 million tons in 2017, with per capita consumption reaching 8.5 pounds in 2019 (Li et al., 2018; OECD, 2019). Due to the fast-growing Chinese demand and limited domestic production, China has emerged as the world's second-largest beef importer, with both the quantity and value of imports more than doubling since 2014. China imported approximately one million tons of beef in 2018, a 51% increase over its total beef imports in 2017, and a 160-fold increase since 2000 (UN Statistics Division, 2018). Despite the uncertainty surrounding trade with China created by the Trump administration's trade policies, the potentially profitable opportunities for American producers warrant the analysis of the Chinese beef market. In particular, information regarding Chinese consumer preferences for U.S. beef and strategies to capitalize on China's growing beef demand is needed given the absence of U.S. beef in the Chinese market for nearly 14 years. This study fills this void by providing an updated understanding of Chinese consumers' preference towards U.S. beef and assessing the potential for U.S. beef in the Chinese market.

Along with growing beef demand, Chinese consumers have become increasingly discerning about the safety of food products (Ortega et al., 2011; Ortega et al., 2012; Wang et al., 2008). Food safety issues arise, in large part, because of asymmetric information between consumers and producers, providing incentives for agents in the food industry to behave opportunistically (Akerlof, 1970; Hölmstrom, 1979; Ollinger & Bovay, 2020; Starbird, 2005). Traceability, which allows for a product to be traced back to the point of origin, has been a recognized tool to mitigate information asymmetry and improve food safety (Hobbs, 2004; Pouliot & Sumner, 2008). As such, investment in traceability systems could be an avenue for meeting Chinese consumers' food safety concerns and therefore capturing market share. However, in practice, conventional centralized traceability systems may not be technically reliable in ensuring food safety, as evidenced by recent and well-publicized food scares and data breaches (Lin et al., 2019a; Tian, 2017; Yiannas, 2018). Centralized traceability systems are managed and maintained by a centralized authority; if that institutional oversight is compromised, data tampering and information fraud may occur (Bodkhe et al., 2020).

Recent advancements in distributed ledger technology (discussed in more detail by Griffin et al., 2020, in this issue) provide a solution to this problem. Blockchain technology, a type of distributed ledger technology, is a decentralized digital ledger used to record information that has been approved by all connected parties, rather than an authority (Sander et al., 2018). Instead of being controlled by a single entity, blockchain-based food traceability systems enable transaction data along the supply chain to be shared and agreed upon by relevant stakeholders, promoting greater trust and transparency. Another distinguishing feature of blockchain is that data written on it cannot be altered without detection. This increases confidence in the data's authenticity and creates incentives for all stakeholders to ensure data accuracy (Yiannas, 2018). These features make food traceability systems based on blockchain technology more capable of advancing food safety by providing authentic information about the food products. Blockchain-based food traceability holds promise in addressing food safety concerns; however, its successful adoption will ultimately depend on acceptance in the consumer market.

To identify alternative markets for the U.S. beef industry, this study utilizes a hypothetical discrete choice experiment to investigate Chinese consumers' demand for U.S. beef and evaluate their acceptance of blockchain-based traceability. We classify Chinese consumers into different segments with consumer willingness to pay (WTP) for beef attributes and socio-demographic characteristics to inform marketing strategies that will enable the U.S. beef industry to capture market share. Our cluster analysis reveals that 63% of Chinese consumers have a negative valuation for U.S. beef relative to domestic beef, indicating a dire need for impactful marketing strategies if U.S. beef is to be successful in the Chinese market. The use of blockchain-based traceability may assist in these efforts, with consumers willing to pay an average premium of approximately $0.60 per pound for beef traced using blockchain technology compared to conventional digital traceability. Consumers who prefer U.S. beef and blockchain-based traceability are more likely to purchase beef online with large quantities per purchase.

This paper contributes to the literature in various ways. First, we provide an updated assessment of Chinese consumers' preference towards U.S. beef. To the best of our knowledge, we are the first academic research study to examine Chinese consumers' attitudes towards U.S. beef and their purchasing behaviors since the U.S. beef industry regained access to the Chinese market after a 14-year ban. This piece of information is timely and essential for the industry to design and implement effective marketing strategies in China. Second, although blockchain traceability can technically address Chinese consumers' food safety concerns, whether and to what extent they respond to the novel technology is unknown. Thus, we evaluate Chinese consumers' acceptance of this type of product traceability to inform the decision of whether to implement blockchain-based traceability in the U.S. beef industry and capitalize on China's growing beef demand. Previous efforts to implement an industry-wide traceability system and standards have proven difficult in the U.S., impeded in part by producer concerns over cost and technological reliability (Schroeder & Tonsor, 2012; Schulz & Tonsor, 2010). With many of the U.S.'s primary Chinese beef market competitors already having adopted traceability systems, identifying and implementing an appropriate traceability system is critical for the U.S. beef industry to remain internationally competitive. How food shoppers react to this nascent food safety practice is also of interest to a broader audience in the food sector. Like Walmart in the U.S. and Jingdong (JD) in China, food retailing giants have already initiated blockchain technology in food traceability systems tracing products such as mangoes, pork, and beef[1] (see Collart and Canales 2020 in this issue for a list of other food companies that have initiated blockchain-based traceability software). Lastly, we inform marketing strategies for the U.S. beef industry by characterizing consumer segments who place a significant price premium on U.S. beef and blockchain-based traceability.

The remainder of the paper is structured as follows. In the next section, we provide a brief overview of the Chinese beef import market and traceability, which are integral to our study design. Then, we give an overview of our methodology detailing the experimental design and econometric models. Next, we discuss the data, followed by a summary of the empirical results from the study. The last section contains a discussion of the implications of our findings for the beef industry and the marketing of beef products in China.

# BACKGROUND

## China's beef import dynamics

China's beef imports are expected to grow to 2.6 million tons in 2020 (USDA FAS, 2019). Figure 1 reports the market share of the main beef imports into mainland China since 2000.

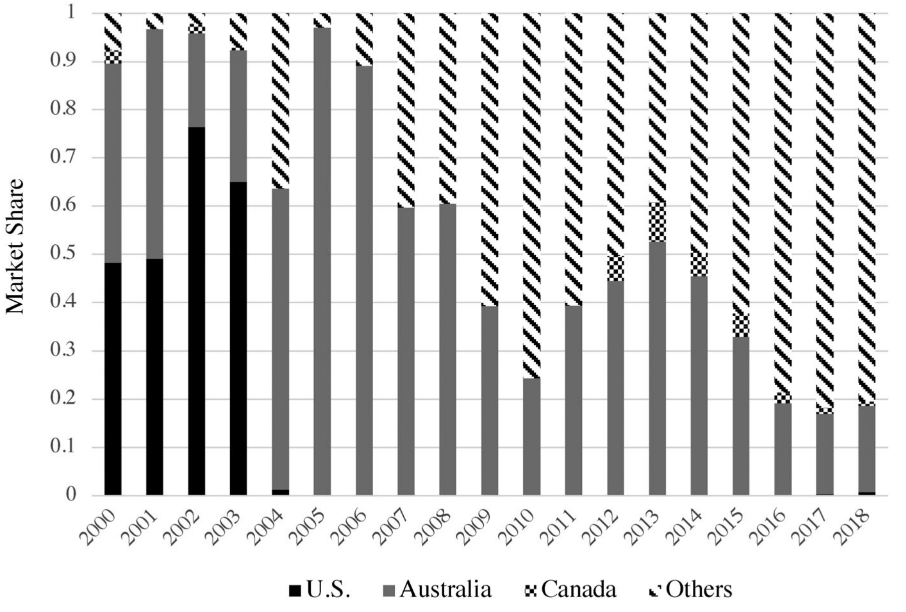



**FIGURE 1** Market share of main beef imports to mainland China, 2000–2018
Source: UN Comtrade

In recent years, Chinese beef imports have mainly originated from five countries: Uruguay, Brazil, Australia, Argentina, and New Zealand (UN Statistics Division, 2018). All beef exported to China is subject to the same traceability requirements (AQSIQ, 2020). Aside from Brazil, each of these countries already has a government-mandated traceability system in place, making all of their beef eligible for export to China under the traceability requirement (Gregg et al., 2018). However, none of these mandated systems require blockchain technology, and China's traceability requirement does not necessarily extend to the provision of that information to consumers.

Canada and Australia have historically been significant trade partners with China. Mao (2008) shows that Chinese tastes are similar to Western tastes for beef quality traits, with high intramuscular fat (marbling) being preferred, followed by tenderness and juiciness. Also, flavor ranks highly among the set of quality traits desired by food consumers. As such, U.S. beef production is well-situated to meet Chinese consumers' demands in terms of beef quality. This places the U.S. among Canada and Australia as primary competitors, given their ability to produce similarly high-quality beef with such desirable traits. Canada does so with a grain-based finishing system similar to the U.S. (Lim et al., 2013), while Australia's largely grass-based system has a world-renowned reputation for high-quality beef products (MLA, 2020). In recent years, the Australian beef industry is partly shifting towards a grain-fed system to cater to the Chinese market (USMEF, 2012). Though other competitors also produce and export high-quality beef, Canada and Australia are most closely positioned in the market with U.S. beef, a position demonstrated by the tendency for these three countries of origin to be highlighted on packaging and marketing materials, in contrast to the other major exporting countries (Hansen et al., 2017). Despite the competitiveness of U.S. beef in the Chinese market as a high-quality product, the American beef industry lost access to Chinese markets in 2003 and has not been able to capitalize on China's growing beef demand because of the negative impact of the bovine spongiform encephalopathy (BSE) outbreak and the ensuing ban (Greene, 2017).

Following the lifting of the 2003 ban on U.S. beef imports in 2017, stringent conditions were placed on beef imports by the Chinese government. According to the USDA-FSIS (2018), beef eligible for export to China must come from cattle less than 30 months of age and be *traceable* such that it can be proven that the cattle were either (1) born, raised, and slaughtered in the U.S.; (2) imported from Canada or Mexico, raised and slaughtered in the U.S.; or (3) imported from Canada or Mexico for direct slaughter in the U.S. Also, exporters are required to participate in the USDA Agricultural Marketing Service (AMS) Export Verification Program for Bovine for China. Such traceability requirements generally exceed current cattle production standards in the U.S. These additional conditions may require substantial investment by U.S. beef producers to capture Chinese market opportunities. The stringency of these traceability requirements reflects the Chinese government's efforts to ensure high food safety standards for its consumers and protect a population that has been subject to an unsafe and unreliable food system for decades which has only begun to be seriously addressed in the last 10 years (Ortega, 2018).

## Food traceability system based on blockchain technology

Blockchain technology offers novelty in food traceability by, among other things, providing full access to authentic information on a product's journey from farm to retailer directly to the consumer. While previous or more conventional food traceability systems have largely maintained records for public safety officials in the event of outbreaks, the consistent and consolidated nature of the information contained in a blockchain allows consumers and any other interested parties to verify the origin and movement of a product through the supply chain. This is achieved by creating a unique tag or identifier beginning when the animal is still on the ranch, which then follows it through the entire processing system, being logged or scanned by supply chain members as it goes. The blockchain system can record and track the temperatures at which the product was held during transport, further improving its utility as a food safety guarantor. Information is then provided by using quick response (QR) codes on end product packaging or even restaurant menus, which the consumer can simply scan with a mobile device to receive a ledger of the product's movements at every step along the supply chain (Biele, 2019). This makes the technology and information extremely accessible to consumers. In addition to the logistics of the product's movement, current blockchain tracing efforts are even proposing means by which the consumer can receive information on the original producer, including the story of the ranch, messages directly from the rancher, and a greater understanding of the operation's safety and sustainability practices (Bandoim, 2019). These sorts of consumer accessibility trials are already underway for startup blockchain tracing firms such as HerdX in the U.S. and BeefLedger in Australia (Bandoim, 2019; Foth & McQueenie, 2019).

# METHODS

## Experimental design

To elicit consumer preferences for U.S. beef products and blockchain traceability, we administered an online choice experiment survey that presented a purchase decision for a beef plate (牛腩[2]) to Chinese consumers. Choice experiments remain by far the most used stated preference technique for various reasons: theoretical consistency, flexibility in allowing participants to opt-out of making a choice, and the ability to elicit trade-offs among a broad set of attributes (Hanley et al., 2001; Louviere et al., 2000; Louviere et al., 2010; Lusk & Schroeder, 2004). This approach presents participants with multiple decision scenarios or tasks and asks them to select the product option or alternative that they most prefer. Each decision comprises two product alternatives, with experimentally designed attribute levels and a no purchase option.

In addition to whether the product was blockchain traceable, we also evaluate country of origin as one of the product attributes to capture consumers' perception of beef imports, which is a significant source of China's beef supply. Levels for country of origin include domestic (China) and three major beef trading partners of China (U.S., Australia, and Canada). Australia and Canada were chosen due to their similar positions in the Chinese market, offering high-quality imported beef. Additionally, Canadian, Australian, and U.S. beef tend to be the most common country-of-origin distinctions used in the Chinese beef market as these labels connote the presence of those traits desirable to the Western and Chinese palettes, namely marbling, tenderness, juiciness, and flavor. Furthermore, we explicitly assess preferences for tenderness, which is the most important eating quality trait for Chinese beef consumers (Mao et al., 2016). As income rises, consumers will increasingly demand both safety- and quality-assured beef products (Liu et al., 2009). Other studies have also emphasized the importance of tenderness in beef purchasing decisions (Caputo et al., 2016; Gao & Schroeder, 2009; Loureiro & Umberger, 2007; Lusk et al., 2001). Finally, product price is included as it is a significant determinant of product choice, and it can be used to derive a monetary evaluation of willingness to pay. Price levels used in the design range from 28 RMB/500 g to 73 RMB/500[3] g. These prices reflect the low-end and high-end market prices at the time of this study. Table 1 provides a summary of the selected product attributes and attribute levels.

A full factorial design with two alternatives would require 4096 ($4^{2x2} \times 2^{2x2}$) different choice tasks given our design specifications. To reduce the number of choice tasks shown to respondents during the survey, using the generators described by Street and Burgess (2007), we obtained a practical set of 16 choice sets, with a D-efficiency 95.82%. The 16 choice sets were then randomly grouped into two blocks (eight choice tasks per block), and the participants were randomly assigned into one of the two blocks. Each choice task includes two product alternatives with experimentally designed attribute levels and an opt-out option. The inclusion of an opt-out alternative better simulates a real market situation. The order in which the eight choice

**TABLE 1** Attributes and attribute levels in the experiment

| Attributes | Levels |
|---|---|
| Country of origin | Domestic |
| | U.S. |
| | Australia |
| | Canada |
| Blockchain traceability | Blockchain traceable |
| | Traceable |
| Price (RMB/500 g) | 28, 43, 58, 73 |
| Tenderness | Has tenderness claim |
| | Does not have tenderness claim |

tasks were presented was randomly varied across subjects. A sample choice task is presented in Figure 2.

Before the choice tasks, we also provide information about blockchain traceability to respondents (see Appendix). The information shown to respondents briefly describes blockchain technology, blockchain traceability, and its advantages over conventional digital traceability systems. Considering that blockchain technology is novel, and its application in food traceability systems is not commonly known, the provision of information helps respondents better evaluate product alternatives in the choice tasks.

## Technology readiness measurement

To measure consumers' propensity to embrace novel technologies such as blockchain traceability, we implement the Technology Readiness Index (TRI) scale originally developed by Parasuraman (2000). Technology readiness refers to a person's propensity to embrace and use new technologies for accomplishing goals in home life and at work (Parasuraman, 2000). Significant technological changes have occurred since the original version of the TRI was published about two decades ago. Therefore, we adopt an updated version, TRI 2.0, which is a reliable and effective tool for consumer segmentation (Parasuraman & Colby, 2015). The TRI score ranges from 1 to 5, with higher scores indicating higher levels of technology readiness. The index has been widely used to assess consumers' attitudes towards self-service technologies such as online shopping and mobile payment in developed and developing countries (Mummalaneni et al., 2016; Wiegard & Breitner, 2019; Zulkifly et al., 2016).

The index consists of four dimensions: optimism, innovativeness, discomfort, and insecurity. Optimism and innovativeness are drivers of technology adoption, measuring the degree to which individuals believe that technology can benefit their lives and the desire to try new technologies. In contrast, discomfort and insecurity are inhibitors. Discomfort assesses the extent to which respondents feel they lack control of and confidence with technology, and insecurity measures distrust and skepticism of technology.

To elicit the four dimensions of consumer technology orientation, the TRI 2.0 was adopted through a 16-item measurement scale. Each dimension has 4-item scale questions, and each question asks respondents to evaluate an attitude statement about technology using a Likert-type scale from 1 (strongly disagree) to 5 (strongly agree). For example, a statement that measures the dimension of optimism is “New technologies contribute to a better quality of life.” The order of the 16 statements' presentation was randomized following Parasuraman and


**FIGURE 2** An example of a choice task [Color figure can be viewed at wileyonlinelibrary.com]

Colby (2015). We calculated a respondent's score of each dimension by taking the mean value of the responses to the four items measuring that dimension. The overall TRI score is the mean score on the four dimensions after reverse coding the scores on discomfort and insecurity.

## Econometric model and willingness-to-pay

An indirect utility function based on Lancaster's theory of consumer demand was specified (Lancaster, 1966) to model consumers' beef purchasing decisions. Following random utility theory (McFadden, 1974), choice experiments rely on the assumption that the utility of individual $n$ choosing alternative $j$ in choice situation $t$ can be expressed as:

$$U_{njt} = V_{njt} + \varepsilon_{njt} \tag{1}$$

where $U_{njt}$ denotes the utility consumer $n$ obtains from the $j^{\text{th}}$ alternative in choice scenario $t$.

$V_{njt}$ is the representative portion of the utility function, which depends on the experimentally designed product attributes for alternative $j$, and $\varepsilon_{njt}$ is the stochastic and unobservable (to researchers) component.

We estimate a mixed logit model with utilities specified in WTP space with correlated parameters. Models specified in WTP space relax the assumption of a fixed price coefficient (Scarpa et al., 2008), and the estimated coefficients can directly be interpreted as marginal WTP values (Scarpa & Willis, 2010). Consumers' preferences for a given attribute are likely to be correlated with their preferences for another attribute (Hess & Train, 2017). In our case, the preference for traceability may correlate with the desire to buy imported beef products. As such, we impose correlations among taste coefficients when estimating our model. The utility function in WTP space can be described as:

$$U_{njt} = \theta_n\left(-PRICE_{njt} + \beta_{n1}Block_{njt} + \beta_{n2}Tender_{njt} + \beta_{n3}USA_{njt} + \beta_{n4}CAN_{njt} + \beta_{n5}AUS_{njt} + ASC\right) + \varepsilon_{njt} \tag{2}$$

where $\theta_n$ is a random positive scalar representing the price/scale parameter; $PRICE_{njt}$ is a continuous variable populated with the four price levels in the design; $Block_{njt}$ and $Tender_{njt}$ are dummy variables for the blockchain traceability and tenderness attributes; $USA_{njt}$, $CAN_{njt}$ and $AUS_{njt}$ are also dummy variables, and they take a value of 1 when the product originates from the U.S., Canada, or Australia, respectively, and 0 otherwise; $ASC$ is the alternative specific constant of the no-purchase option; the $\beta$s are the random coefficients of the estimated WTP values; $\varepsilon_{njt}$ is the random error term, which follows a Type I Extreme Value distribution.

## Market segmentation and cluster analysis

To assess the Chinese market potential for U.S. beef and inform business decisions, we conduct segmentation analysis through clustering. Cluster analysis is a statistical method that builds homogeneous groups out of a heterogeneous population (Hair et al., 1998) by sorting on a set of multivariate data. After sorting, the observations within each cluster should have similar characteristics, while the clusters themselves are dissimilar. Clustering techniques have been widely used for segmentation analyses in different fields such as biology, psychology, marketing, and economics.

We use a two-stage clustering method following Petrovici and Gorton (2005) and Van den Broeck et al. (2017). First, Ward's clustering method is applied to determine the optimal number of clusters, maximizing heterogeneity across clusters and minimizing heterogeneity within clusters. Ward's method is a hierarchical clustering procedure where the squared Euclidean distance between points is minimized. The second step is K-means cluster analysis to correct possible misclassification of observations at the boundaries between clusters (Jansen et al., 2006). As one of the most popular and efficient clustering techniques, the K-means method organizes similar groups by minimizing the mean squared distance from each point to its nearest center (Jain, 2010). For our study, the set of variables used in this cluster analysis are Chinese consumers' WTP values for U.S. beef and blockchain traceability, TRI scores, beef consumption and purchasing habits, and demographics. To better understand which aspects characterize the different groups, statistical tests (e.g., F-test or Chi-square test) are used to determine significant differences in variables between clusters.

## DATA

A sample of urban Chinese consumers was recruited by Qualtrics, a professional market research company, in November 2018. All respondents were excluded a priori if they were younger than 18 years of age, were not the primary household grocery shopper, or had not purchased beef in the last month. A total of 383 valid observations were collected. Responses were geographically diverse, being spread across different regions of China.[4] Nearly 60% of respondents were female, had an average age of 35 years, and reported having four to five people in their households (Table 2). The majority of the study participants had a college degree, a monthly household income of more than RMB 13,000. The average respondent purchased beef at least once a week in a traditional retail channel (wet market or domestic supermarket). Compared to Ortega et al. (2016), who studied beef consumers in Beijing, there is a moderate overrepresentation of female and younger respondents in our sample. This is expected as we required our respondents to be primary household grocery shoppers, and in China, women are mainly responsible for household food shopping and preparation. Our sample is comparatively young as these individuals are usually more open and willing to participate in online surveys. This might be considered an advantage when assessing potential markets (Sanjuán-López & Resano-Ezcaray, 2020). Descriptive statistics of consumer sociodemographics, beef purchasing and consumption habits, and blockchain purchasing information are presented in Table 2. Chinese consumers stated a preference for domestic beef, followed by beef from Australia, Canada, and the U.S. This descriptive ranking reflects the absence of U.S. beef for almost 14 years due to the beef import ban after the BSE disease outbreak. Knowledge was elicited using a single self-reported question, "How knowledgeable would you say you are about blockchain traceability?" on a Likert-type scale from 1 (not at all knowledgeable) to 9 (extremely knowledgeable). Our sample is knowledgeable about blockchain traceability to an extent, with an average self-reported score of 5.38. Regarding purchase experience, approximately 45% of consumers have purchased products with blockchain traceability, though the majority (86%) of our respondents claimed that they had heard about blockchain technology. This corresponds to the high TRI scores found in our sample. In Table 3, we report the calculated means for TRI and its four

**TABLE 2** Descriptive statistics

| Variables | | Sample Data |
|---|---|---|
| Demographics | | |
| Age | Years | 35.20 (8.56) |
| Female | % | 58.22 |
| Household income | % | |
| | Low | 5.48 |
| | Medium | 52.48 |
| | High | 42.04 |
| College | % | 84.86 |
| Household size | Persons | 4.49 (1.29) |
| Region of residence | % | |
| | North | 30.96 |
| | Central | 5.67 |
| | East | 38.60 |
| | South | 15.02 |
| | West | 9.75 |
| Purchasing and consumption habits | | |
| Beef purchase frequency | % | |
| | Daily | 3.13 |
| | Every other day | 6.27 |
| | 2–3 times per week | 39.95 |
| | Weekly or less | 50.65 |
| Beef purchase location | % | |
| | Wet market | 31.07 |
| | Domestic supermarket | 38.64 |
| | International supermarket | 18.54 |
| | Online store | 11.75 |
| Most preferred origin | % | |
| | China | 43.34 |
| | U.S. | 15.93 |
| | Canada | 16.45 |
| | Australia | 24.28 |
| Heard about blockchain technology | % | 85.9 |
| Bought blockchain-traced products | % | 44.15 |
| Blockchain traceability knowledge | | 5.38 (2.16) |
| Beef quantity per purchase | Grams | 808.70 (391.48) |
| Beef weekly consumption | % | |
| | Low | 30.03 |
| | Medium | 60.83 |
| | High | 9.14 |
| No. of individuals | | 383 |

*Note:* Standard deviations are reported in parentheses when appropriate. For beef weekly consumption, less than 500 g is indicated as low, 500 to 2000 g is medium and above 2000 g is high consumption. For household income, low indicates household income is lower than 7000 RMB, medium means 7000 to 19,000 RMB, and high means above 19,000 RMB per month. Blockchain subjective knowledge was measured using a single self-report item on a Likert scale from 1 (not at all knowledgeable) to 9 (extremely knowledgeable).

**TABLE 3** Technology Readiness Index (TRI) statistics

| | Our sample (2018) | U.S. sample (2012) | Taiwan sample (2016) |
|---|---|---|---|
| Optimism | 4.27 | 3.75 | 3.66 |
| Innovativeness | 3.81 | 3.02 | 3.28 |
| Discomfort | 2.89 | 3.09 | 2.40 |
| Insecurity | 3.09 | 3.58 | 2.89 |
| Overall TRI | 3.51 | 3.02 | N/A |

*Note:* U.S. and Taiwan sample statistics are from Parasuraman and Colby (2015) and Chen and Lin (2018), respectively. Chen and Lin (2018) used a seven-point scale; thus, the values in Table 3 for the Taiwan sample are converted to a four-point scale for comparison purposes.

dimensions and values obtained from relevant studies for comparison purposes (Table 3). TRI's overall value is 3.51, showing that consumers have a relatively strong propensity to embrace novel technologies. Specifically, optimism scored highest (4.27) among the four TRI dimensions, while discomfort scored lowest (2.89), which indicates that Chinese consumers have a very positive view of technology and believe that technology offers people increased control, flexibility, and efficiency in their lives. Compared with the U.S., Chinese consumers are more optimistic and innovative, with a higher level of technology readiness. U.S. respondents are generally more skeptical and distrustful of technology's ability to work properly, often feeling overwhelmed by it (Meng et al., 2009). Interestingly, the story was different 10 years ago—U.S. consumers were more likely to embrace new technologies than Chinese consumers in terms of overall TRI and its four dimensions (Hmielowski et al., 2019; Meng et al., 2009; Wang et al., 2017).

We generate heat maps with follow-up questions to the choice experiment asking respondents to indicate the level of importance that they assigned to various product packaging areas (Figure 3). The left and right panels of Figure 3 are identical in terms of beef package size, price, tenderness, and blockchain traceability, except that the left package denotes domestic beef while the right one originates from the U.S. Consumers were asked to evaluate the panels separately. In both the packages, 10% of consumers indicated the country of origin as the most important factor when considering beef purchase. Our data reveals that consumers consider tenderness (34%) and blockchain traceability (31%) as the most important factors in their purchasing decisions. In the two scenarios, approximately 10% of respondents note price to be the driving force in beef purchases. An important finding is that relative to domestic beef, fewer consumers indicated price as being the dominant factor (18% vs. 12%), implying that consumers may be less sensitive to costs when buying the U.S. beef products, which implies promising profit opportunities for the U.S. beef industry.

## RESULTS

Estimates from the mixed logit model in WTP space with correlated parameters are reported in Table 4. Mixed logit models allow for random taste, but such power significantly relies on a prior distributional assumption about the preferences (Balcombe et al., 2009). As such, we test various distributions before specifying normally distributed parameters for blockchain

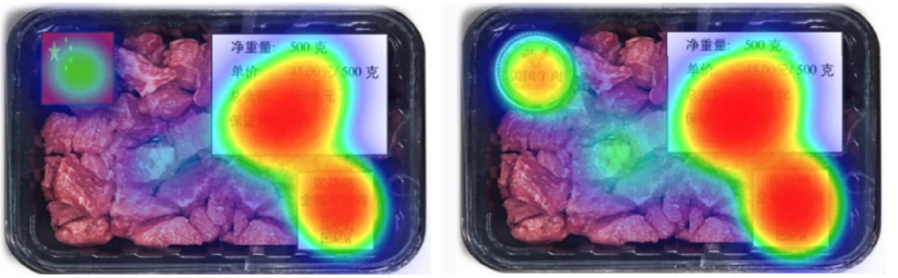


**FIGURE 3** Heat map analysis. The left panel is domestic (Chinese) beef, and the right is imported U.S. beef [Color figure can be viewed at wileyonlinelibrary.com]

traceability, tenderness, and country of origin coefficients, and one-sided triangular distribution for the scale/price coefficient.

The estimation of Equation (2) (Table 4) indicates strong heterogeneity in consumer preferences for blockchain traceability and country of origin as the estimated standard deviations for these attributes differ significantly from zero. In terms of country of origin, Australian beef received the highest price premium from consumers. On average, Chinese consumers are willing to pay $1.11 per pound to "upgrade" domestic beef to Australian beef. This finding deviates from the descriptive rank analysis in which consumers preferred domestic products most.[5] Still, it is consistent with other studies that found that Chinese beef shoppers are willing to pay more for Australian beef products over U.S. or domestic beef (Ortega et al., 2016). Our estimation results indicate that consumers, in general, value U.S. and Canadian beef in a way similar to domestic beef. While the mean point estimate for U.S. beef is not statistically significant, there is strong preference heterogeneity around consumer preference for U.S. beef (see Figure 4). Consumer valuation for U.S. beef ranges from −$18 to $10 per pound. Slightly over half of the respondents (54%) require compensation before being indifferent between U.S. beef and domestic beef, and, conversely, the remaining 46% are willing to pay more for U.S. beef. In general, our current results are consistent with the finding of Ortega et al. (2016) that Chinese consumers prefer Australian beef over U.S. beef. This is likely due to the proliferation of Australian beef in China after the U.S. BSE outbreak, which led to the ban of U.S. beef in China from 2003 to 2017. Moreover, the recent tariff dispute between the U.S. and China has resulted in higher U.S. meat prices relative to competitors. Our results indicate that despite capturing consumers' attention, tenderness is not an important driver of beef purchases in China (insignificant mean and standard deviation estimates).

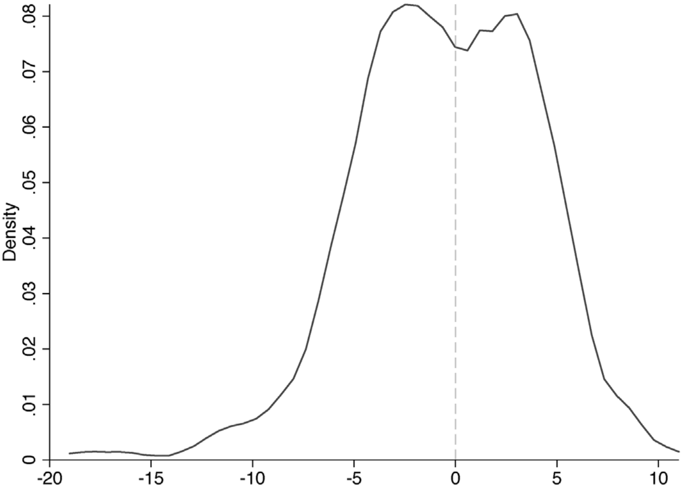
We find that blockchain-based traceability exhibits a statistically significant influence on consumers' overall utility. Consumers are willing to pay approximately $0.60 per pound for blockchain traceable beef compared to beef supported with a regular digital traceability system, which is standard for imported meat products. By quantifying consumer preference and valuation for blockchain traceability, we provide a baseline statistic that can be used for market feasibility and investments in blockchain traceability along Chinese meat supply chains. We also find a significant positive correlation (0.89) between individual WTPs for U.S. beef and blockchain-based traceability. Individuals who favor U.S. beef are willing to pay a high premium for blockchain traceability, and *vice versa*. The complementarity between U.S. beef and blockchain traceability reveals that adopting blockchain traceability would benefit the U.S. beef industry by generating more revenues from exporting beef to China.

**TABLE 4** Willingness to pay results ($/lb. equivalent)

| Variables | Mean | SD |
|---|---|---|
| Blockchain | 0.63** | 1.31*** |
| | (0.31) | (0.49) |
| Tender | 0.32 | 1.23 |
| | (0.28) | (0.96) |
| U.S. | −0.42 | 6.54*** |
| | (0.60) | (0.81) |
| Australia | 1.11** | 4.66*** |
| | (0.49) | (1.19) |
| Canada | 0.44 | 4.83** |
| | (0.51) | (2.09) |
| ASC | −3.78*** | |
| Model statistics | | |
| No. of parameters | 22 | |
| No. of choices | 3064 | |
| No. of individuals | 383 | |
| Log-likelihood | −2492 | |
| AIC/N | 1.64 | |

Note: Asterisks ***, and ** indicate significance at the 0.01, and 0.05 levels. Standard errors are in parentheses. Models were estimated in local currency and quantity units. The exchange rate at the time of this study was 1 US dollar = 6.96 RMB.

**FIGURE 4** WTP distribution of U.S. beef, $/lb. equivalent




We further employ cluster analysis to inform market segmentation for U.S. and blockchain traceable beef. Table 5 shows the differences in WTPs, demographics, and beef purchasing characteristics for three consumer segments. The largest cluster, accounting for 38% of respondents, is referred to as "Blockchain curious" as they have a modest willingness to pay for blockchain traceability ($0.52 per pound). While not willing to pay a premium for U.S. beef, consumers in this class tend to purchase beef more from emerging retailers such as online stores and have some blockchain purchasing experience and knowledge. Roughly 25% of the sample belongs to the cluster whom we label as "traditionalists." These consumers have a negative valuation for both blockchain traceability and U.S. beef, preferring domestic products. Compared to other segments, "traditionalists" have the lowest income, purchase the lowest amounts of beef during each grocery shopping trip, and lack knowledge or experience about blockchain-based traceability. In contrast, "blockchain enthusiasts" (37% of the sample) are willing to pay a significant premium for blockchain traceability and U.S. beef. Their average WTP is almost $4.00 per pound for beef originating from the U.S. and $1.39 per pound for blockchain-traced beef, which implies the greatest market potential for U.S. beef. This segment has a fairly high level of technology readiness, household income, and subjective knowledge regarding blockchain traceability. Consumers in this group are also more educated, purchase beef in larger quantities more frequently and patronize online retailers. This implies that consumers who buy beef online may

**TABLE 5** Clustering results

| Variables | Cluster 1 "Blockchain Curious" | Cluster 2 "Blockchain Enthusiasts" | Cluster 3 "Traditionalist" | Δ*p*-value |
|---|---|---|---|---|
| WTP Blockchain ($/lb. equivalent) | 0.52 | 1.39 | −0.39 | 0.05 |
| WTP US ($/lb. equivalent) | −1.13 | 3.90 | −6.00 | 0.05 |
| TRI | 3.48 | 3.61 | 3.47 | 0.24 |
| Age | 35 | 36 | 35 | 0.08 |
| Female (%) | 63 | 57 | 52 | 0.18 |
| College (%) | 83 | 90 | 81 | 0.27 |
| Household income | 7.98 | 8.85 | 7.52 | 0.33 |
| Beef quantity per purchase (g) | 806 | 837 | 768 | 0.09 |
| Bought beef weekly (%) | 28 | 24 | 31 | 0.51 |
| Bought beef from online store (%) | 10 | 15 | 9 | 0.02 |
| Bought Blockchain products (%) | 50 | 50 | 34 | 0.03 |
| Blockchain subjective knowledge | 5.43 | 5.69 | 4.82 | 0.06 |
| Clusters composition | | | | |
| No. of individuals | 145 | 143 | 95 | |
| Market share | 38% | 37% | 25% | |

*Note:* WTP Blockchain (RMB/500 g) and WTP US (RMB/500 g) are average willingness to pay values for 500 g of blockchain traceable beef and U.S. beef, respectively. Household income was included as a continuous variable in the analysis. For reference, a value of 7 denotes that monthly income falls in the range of RMB 13,000–14,999, a value of 8 RMB 15,000–16,999, and a value of 9 RMB 17,000–18,999.

be target customers for U.S. and blockchain traceable beef products. This parallels findings from previous research that has identified e-commerce as a promising retail channel for premium meat products in China (Lin et al., 2019b).

## IMPLICATIONS AND CONCLUSION

In this paper, we examine how much value Chinese consumers place on blockchain-based traceability in their demand for domestic and imported (U.S., Canada, Australia) beef products using a discrete choice experiment. We further classify consumers into different market clusters based on their valuations for beef products and sociodemographic characteristics. Our segmentation analysis suggests that 63% of Chinese consumers have a negative valuation for U.S. beef relative to domestic beef, indicating a dire need for impactful marketing strategies if U.S. beef is to be successful in the Chinese market. The use of blockchain-based traceability may assist in these efforts, given that blockchain traceability is a significant driver of beef purchasing decisions, with consumers willing to pay an average premium of $0.63 per pound compared to regular digital traceability.

Data from our heat map illustrates that 31% of consumers in our sample consider blockchain-based traceability the most important factor when buying beef, and our market segmentation analysis suggests that there is a group of respondents (37%) who would pay significant premiums for both U.S. beef and blockchain traceable beef products. This implies promising opportunities for the U.S. beef industry and blockchain traceability investors, given the current traceability requirements for exporting U.S. beef to China. A complementary relationship between U.S. beef and blockchain-based traceability provides support for the use of blockchains by the U.S. beef industry to gain market share in China. Our market segmentation analysis also finds that consumers who are willing to pay a premium on U.S. beef consistently prefer blockchain traceability. Thus, if the U.S. beef industry is to successfully market their product in China, the employment of blockchains may significantly improve their ability to reach the most receptive consumers.

Moreover, we find that consumers who prefer these two attributes are more likely to purchase beef online. Imported meat makes up a considerable portion of online meat sales, with imports comprising nearly a third of the meat sold through JD.com in 2016 (Patton, 2017). This result is encouraging for U.S. beef exporters as Chinese online grocery sales continue to grow. Since online sales are already a major outlet for imported beef, and online beef purchasers tend to view U.S. beef more favorably, then a focus on online beef sales could increase the ease with which U.S. beef exporters may be able to capture market share in the Chinese market. Additionally, these online purchases tend to occur in relatively large quantities per purchase, which has implications for how U.S. beef exporters may target potential customers. To gain more exposure and compete directly with Australian products, the U.S. beef industry could increase its marketing activities, for example hosting American barbecue day with large retailers in China. U.S. beef products could also benefit from being featured in China's giant e-commerce platforms, especially during the Chinese New Year. Other studies have also found that product ratings and the number of reviews are important determinants of Chinese online shoppers' product choices (Lin et al., 2019b). These determinants may have consequences for the U.S. beef industry entering the online grocery market in China. It would be beneficial for U.S. beef companies to direct marketing efforts to increase product ratings and incentivize consumers to share their experiences on online platforms. To this end, developing a base of consumer reviews soon after the product launch would provide consumers with valuable information and help increase market share.

The results of this study further inform the U.S. beef industry as they increase promotional efforts following a nearly 14-year trade ban in China by contextualizing their market potential relative to major competitors. Our results provide important information on Chinese consumers' beef preferences for country of origin and indicate that Chinese consumers prefer Australian over domestic and North American beef. With some Australian beef exports already employing blockchain technology (Smith, 2017) and Chinese consumers having an established preference for Australian beef, U.S. beef exporters must carefully position themselves alongside their competitors to effectively win a larger market share. Adopting blockchain traceability technology may be imperative to this positioning.

We do not exclude the possibility that our results may be subject to hypothetical bias. Although our survey does not explicitly include hypothetical bias mitigation methods, we carefully select our respondents to be experienced food purchasers and also provide blockchain information to help respondents better evaluate their choices. The literature has suggested that hypothetical bias mitigation techniques appear to be ineffective and redundant among experienced participants or when product information is provided (Fifer et al., 2014; List, 2001), in part because hypothetical bias is less likely to exist in these contexts. We also note that, while our sample composition is comparable to other studies', our sample size is insufficient to explore regional heterogeneity. Additional work focused on regional preferences for beef products is recommended to develop region-specific positioning strategies. Our results provide evidence that a suitable market for blockchain traceable U.S. beef exists in China; however, future research is needed to understand American producers' attitudes towards this particular market opportunity. Traceability efforts have historically been met with some resistance in the U.S. (Schroeder & Tonsor, 2012; Schulz & Tonsor, 2010). Future studies may aim to investigate whether blockchains will be viewed any differently, particularly in the context of its potential to enhance accessibility to the Chinese food market. Additionally, the implications of blockchain-based traceability adoption in the U.S. for American consumers merits investigation. Blockchain traceability adoption in the U.S. may be especially important as sufficient interest from American consumers may safeguard against losses in an unstable trade environment with China.

## ACKNOWLEDGMENTS

This work was supported in part by the USDA National Institute of Food and Agriculture, Hatch project 04189, and Michigan State University's AgBioResearch. The authors acknowledge comments and suggestions from two anonymous reviewers.

## ENDNOTES

[1] For a complete list of food products that could be tracked by blockchain-based traceability in Walmart, check the website https://www.hyperledger.org/learn/publications/walmart-case-study.

[2] Beef plate (牛腩) is a common cut of beef in China, mainly used for stewing or braising. The most similar American equivalent cut from the plate is short ribs.

[3] 1 US dollar = 6.96 RMB at the time of this study.

[4] The regional distribution of our sample generally corresponds to the distribution of the urban population in China, with North 31% (our sample) vs. 22% (the population), East 38% vs. 32%, Central 5% vs. 14%, South 15% vs. 18%, and West 10% vs. 14% (National Bureau of Statistics of China 2019), with slightly more respondents in the North, and fewer from the central provinces.

[5] This result is not surprising, as research has shown that the descriptive rank question and choice experiment yield different choice outcomes (Caparros et al., 2008; Merino-Castello, 2003). Adamowicz et al. (1994) emphasize results from choice experiments since they are closer to real-market decisions.

## REFERENCES

Adamowicz, Wiktor, Jordan Louviere, and Michael Williams. 1994."Combining Revealed and Stated Preference Methods for Valuing Environmental Amenities." *Journal of Environmental Economics and Management* 26 (3): 271–292.

Akerlof, George A. 1970."The Market for 'Lemons': Quality Uncertainty and the Market Mechanism." *Quarterly Journal of Economics* 84(3): 488–500.

AQSIQ. 2020. Meat Registration Application. Accessed July 6, 2020. https://www.aqsiq.net/application/meat-registration

Balcombe, Kelvin, Ali Chalak, and Iain Fraser. 2009."Model Selection for the Mixed Logit with Bayesian Estimation." *Journal of Environmental Economics and Management* 57(2): 226–237.

Bandoim, Lana. 2019. "Can Blockchain and Chip Technology Improve Beef Sourcing Transparency?" *Forbes*. Accessed July 8, 2020. https://www.forbes.com/sites/lanabandoim/2019/04/30/can-blockchain-and-chip-technology-improve-beef-sourcing-transparency/#441ecf473284

Biele, Chad. 2019. *UPS and HerdX Deliver Blockchain-Verified Beef from U.S. to Japan*. UPS Press Release, November 11, 2019. Accessed July 8, 2020. https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1573245679338-340&WT.mc_id=UPSCOM_NEWSANDINFO_HERDX_PRESSRELEASE_111119

Bodkhe, Umesh, Sudeep Tanwar, Karan Parekh, Pimal Khanpara, Sudhanshu Tyagi, Neeraj Kumar, and Mamoun Alazab. 2020. "Blockchain for Industry 4.0: A Comprehensive Review." *IEEE Access* 8: 79764–79800.

Collart, A.J, and Canales, E. 2020. "How might broad adoption of blockchain-based traceability impact the U.S. fresh produce supply chain?" *Forthcoming in Applied Economic Perspectives and Policy*

Caparros, Alejandro, Jose L. Oviedo, and Pablo Campos. 2008."Would You Choose Your Preferred Option? Comparing Choice and Recoded Ranking Experiments." *American Journal of Agricultural Economics* 90(3): 843–855.

Caputo, Vincenzina, Riccardo Scarpa, and Rodolfo M. Nayga. 2016."Cue Versus Independent Food Attributes: The Effect of Adding Attributes in Choice Experiments." *European Review of Agricultural Economics* 44(2): 211–230.

Fifer, Simon, John Rose, and Stephen Greaves. 2014."Hypothetical Bias in Stated Choice Experiments: Is It a Problem? And if So, How Do We Deal With It?" *Transportation Research Part A: Policy and Practice* 61: 164–177.

Foth, Marcus and John McQueenie. 2019. "Creatives in the Country? Blockchain and Agtech can Create Unexpected Jobs in Regional Australia." *The Conversation*, June: 1–5.

Gao, Zhifeng, and Ted C. Schroeder. 2009."Effects of Label Information on Consumer Willingness-to-Pay for Food Attributes." *American Journal of Agricultural Economics* 91(3): 795–809.

Greene, Joel L. 2017. "U.S. Beef: It's What's For China." Congressional Research Report no. IN10724. U.S. Foreign Agricultural Service. July 22, 2017. Accessed October 4, 2019. https://fas.org/sgp/crs/row/IN10724.pdf

Griffin, T.W., Harris, K.D., Ward, J.K., Goeringer, P., and Richard, J.A. 2020. "Three digital agriculture problems in cotton solved by distributed ledger technology." *Forthcoming, Applied Economic Perspectives and Policy.*

Gregg, David, Dave Juday, and Matt Herrington. 2018. *Comprehensive Feasibility Study: U.S. Beef Cattle Identification and Traceability Systems*. Arlington, VA: World Perspectives, Inc.

Hanley, Nick, Susana Mourato, and Robert E. Wright. 2001."Choice Modelling Approaches: A Superior Alternative for Environmental Valuation?" *Journal of Economic Surveys* 15(3): 435–462.

Hansen, James, Mary A. Marchant, Francis Tuan, and Agapi Somwaru. 2017."US Agricultural Exports to China Increased Rapidly Making China the Number One Market." *Choices* 32(2): 1–6.

Hair, Joseph F., William C. Black, Barry J. Babin, Rolph E. Anderson, and R.L. Tatham. 1998. *Multivariate Data Analysis*. Upper Saddle River, NJ: Prentice hall.

Hess, Stephane, and Kenneth Train. 2017."Correlation and Scale in Mixed Logit Models." *Journal of Choice Modelling* 23: 1–8.

Hmielowski, Jay D., Amanda D. Boyd, Genevieve Harvey, and Jinho Joo. 2019."The Social Dimensions of Smart Meters in the United States: Demographics, Privacy, and Technology Readiness." *Energy Research & Social Science* 55: 189–197.

Hölmstrom, Bengt. 1979."Moral Hazard and Observability." *The Bell Journal of Economics* 10(1): 74–91.

Hobbs, Jill E. 2004."Information Asymmetry and the Role of Traceability Systems." *Agribusiness* 20(4): 397–415.

Jain, Anil K. 2010."Data Clustering: 50 Years beyond K-Means." *Pattern Recognition Letters* 31(8): 651–666.

Jansen, Hans G., John Pender, Amy Damon, Willem Wielemaker, and Rob Schipper. 2006."Policies for Sustainable Development in the Hillside Areas of Honduras: A Quantitative Livelihoods Approach." *Agricultural Economics* 34(2): 141–153.

Lancaster, Kelvin J. 1966."A New Approach to Consumer Theory." *Journal of Political Economy* 74(2): 132–157.

Li, Xiang Zi, Chang Guo Yan, and Lin Sen. Zan. 2018."Current Situation and Future Prospects for Beef Production in China—A Review." *Asian-Australasian Journal of Animal Sciences* 31(7): 984.

Lim, Kar H., Wuyang Hu, Leigh J. Maynard, and Ellen Goddard. 2013."US Consumers' Preference and Willingness to Pay for Country-of-Origin-Labeled Beef Steak and Food Safety Enhancements." *Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie* 61(1): 93–118.

Lin, Qijun, Huaizhen Wang, Xiaofu Pei, and Junyu Wang. 2019a."Food Safety Traceability System Based on Blockchain and EPCIS." *IEEE Access* 7: 20698–20707.

Lin, Wen, David L. Ortega, and Vincenzina Caputo. 2019b."Are Ex-Ante Hypothetical Bias Calibration Methods Context Dependent? Evidence from Online Food Shoppers in China." *Journal of Consumer Affairs* 53(2): 520–544.

List, John A. 2001."Do Explicit Warnings Eliminate the Hypothetical Bias in Elicitation Procedures? Evidence from Field Auctions for Sportscards." *American Economic Review* 91(5): 1498–1507.

Liu, Hongbo, Kevin A. Parton, Zhang Yue Zhou, and Rod Cox. 2009."At-Home Meat Consumption in China: An Empirical Study." *Australian Journal of Agricultural and Resource Economics* 53(4): 485–501.

Loureiro, Maria L., and Wendy J. Umberger. 2007."A Choice Experiment Model for Beef: What US Consumer Responses Tell us about Relative Preferences for Food Safety, Country-of-Origin Labeling and Traceability." *Food Policy* 32(4): 496–514.

Louviere, Jordan J., Terry N. Flynn, and Richard T. Carson. 2010."Discrete Choice Experiments Are Not Conjoint Analysis." *Journal of Choice Modelling* 3(3): 57–72.

Louviere, Jordan J., David A. Hensher, and Joffre D. Swait. 2000. *Stated Choice Methods: Analysis and Applications*. Cambridge, UK: Cambridge University Press.

Lusk, Jayson L., Thomas L. Marsh, Ted C. Schroeder, and John A. Fox. 2001."Wholesale Demand for USDA Quality Graded Boxed Beef and Effects of Seasonality." *Journal of Agricultural and Resource Economics* 26: 91–106.

Lusk, Jayson L., and Ted C. Schroeder. 2004."Are Choice Experiments Incentive Compatible? A Test with Quality Differentiated Beef Steaks." *American Journal of Agricultural Economics* 86(2): 467–482.

Mao, Yanwei, David L. Hopkins, Yimin Zhang, and Xin Luo. 2016."Consumption Patterns and Consumer Attitudes to Beef and Sheep Meat in China." *American Journal of Food and Nutrition* 4(2): 30–39.

Mao, Yanwei. 2008. "Study on Palatability Assurance Critical Control Point of Beef." Master's thesis, Shandong Agricultural University. http://d.wanfangdata.com.cn/Thesis_Y1374525.aspx. Accessed August 12, 2019.

McFadden, Daniel. 1974. *Conditional Logit Analysis of Qualitative Choice Behavior*. New York: Academic Press.

Meng, Juan, Kevin M. Elliott, and Mark C. Hall. 2009."Technology Readiness Index (TRI): Assessing Cross-Cultural Validity." *Journal of International Consumer Marketing* 22(1): 19–31.

Merino-Castello, Anna. 2003. "Eliciting Consumers Preferences Using Stated Preference Discrete Choice Models: Contingent Ranking Versus Choice Experiment." Economics and Business Working Paper 705, Universitat Pompeu Fabra.

MLA (Meat & Livestock Australia). 2020. "Australia's Beef Trade with China." Accessed July 7, 2020. https://www.mla.com.au/news-and-events/industry-news/australias-beef-trade-with-china/#

Mummalaneni, Venkatapparao, Juan Meng, and Kevin M. Elliott. 2016."Consumer Technology Readiness and e-Service Quality in e-Tailing: What Is the Impact on Predicting Online Purchasing?" *Journal of Internet Commerce* 15(4): 311–331.

OECD. 2019. "Meat Consumption (Indicator)." Accessed August 12, 2019. https://doi.org/10.1787/fa290fd0-en.

Ollinger, Michael, and John. Bovay. 2020.“Producer Response to Public Disclosure of Food-Safety Information.” *American Journal of Agricultural Economics* 102(1): 186–201.

Ortega, David L. 2018. “Testimony before the U.S. China Economic Security Review Commission: Hearing on ‘China's Agricultural Policies: Trade, Investment, Safety, and Innovation.’” April 26, 2018. Accessed October 4, 2019. https://www.uscc.gov/sites/default/files/Ortega%20Testimony%204-13-18.pdf

Ortega, David L., Soo Jeong Hong, H. Holly Wang, and Laping Wu. 2016.“Emerging Markets for Imported Beef in China: Results from a Consumer Choice Experiment in Beijing.” *Meat Science* 121: 317–323.

Ortega, David L., H. Holly Wang, Nicole J. Olynk, Laping Wu, and Junfei Bai. 2012.“Chinese Consumers' Demand for Food Safety Attributes: A Push for Government and Industry Regulations.” *American Journal of Agricultural Economics* 94(2): 489–495.

Ortega, David L., H. Holly Wang, Laping Wu, and Nicole J. Olynk. 2011.“Modeling Heterogeneity in Consumer Preferences for Select Food Safety Attributes in China.” *Food Policy* 36(2): 318–324.

Parasuraman, A. 2000.“Technology Readiness Index (TRI) a Multiple-Item Scale to Measure Readiness to Embrace New Technologies.” *Journal of Service Research* 2(4): 307–320.

Parasuraman, A., and Charles L. Colby. 2015.“An Updated and Streamlined Technology Readiness Index: TRI 2.0.” *Journal of Service Research* 18(1): 59–74.

Patton, Dominique. 2017. “Smithfield Food Foes Online to Sell U.S. Pork in China.” Reuters (Beijing), October 24. Accessed December 15, 2020. https://www.reuters.com/article/us-china-smithfield-pork/smithfield-foods-goes-online-to-sell-u-s-pork-in-china-idUSKBN1CU07B.

Petrovici, Dan A., and Matthew Gorton. 2005.“An Evaluation of the Importance of Subsistence Food Production for Assessments of Poverty and Policy Targeting: Evidence from Romania.” *Food Policy* 30(2): 205–223.

Pouliot, Sebastian, and Daniel A. Sumner. 2008.“Traceability, Liability, and Incentives for Food Safety and Quality.” *American Journal of Agricultural Economics* 90(1): 15–27.

Sander, Fabian, Janjaap Semeijn, and Dominik Mahr. 2018.“The Acceptance of Blockchain Technology in Meat Traceability and Transparency.” *British Food Journal* 120(9): 2066–2079.

Sanjuán-López, Ana I., and Helena Resano-Ezcaray. 2020.“Labels for a Local Food Speciality Product: The Case of Saffron.” *Journal of Agricultural Economics* 71: 778–797.

Scarpa, Riccardo, and Ken Willis. 2010.“Willingness-to-Pay for Renewable Energy: Primary and Discretionary Choice of British Households' for Micro-Generation Technologies.” *Energy Economics* 32(1): 129–136.

Scarpa, Riccardo, Mara Thiene, and Kenneth Train. 2008.“Utility in Willingness to Pay Space: A Tool to Address Confounding Random Scale Effects in Destination Choice to the Alps.” *American Journal of Agricultural Economics* 90(4): 994–1010.

Schroeder, Ted C., and Glynn T. Tonsor. 2012.“International Cattle ID and Traceability: Competitive Implications for the US.” *Food Policy* 37(1): 31–40.

Schulz, Lee L., and Glynn T. Tonsor. 2010.“Cow-Calf Producer Preferences for Voluntary Traceability Systems.” *Journal of Agricultural Economics* 61(1): 138–162.

Smith, George. 2017. “Blockchain Project Sets out to Defend Australia's World-Class Beef.” *New Food*, December 13. Accessed August 1, 2020. https://www.newfoodmagazine.com/news/46916/australia-beef-blockchain/.

Starbird, S.Andrew. 2005.“Moral Hazard, Inspection Policy, and Food Safety.” *American Journal of Agricultural Economics* 87(1): 15–27.

Street, Deborah J., and Leonie. Burgess. 2007. *The Construction of Optimal Stated Choice Experiments: Theory and Methods*. Hoboken, NJ: John Wiley & Sons.

United Nations (UN) Statistics Division. 2018. *UN Comtrade Database: Trade between China and all Reporters. HS Codes: 0201, 0202, 0203, 0206, 0207*. New York: United Nations. https://comtrade.un.org/data/.

USDA FAS (United States Dept of Agriculture Foreign Agricultural Service). 2019. “China-People Republic of Livestock and Products Annual.” https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Livestock%20and%20Products%20Annual_Beijing_China%20-%20Peoples%20Republic%20of_7-22-2019.pdf.

USDA FSIS (United States Dept of Agriculture Food Safety and Inspection Services). 2018. “Export Requirements for The People's Republic of China.” https://www.fsis.usda.gov/wps/portal/fsis/topics/international-affairs/exporting-products/export-library-requirements-by-country/Peoples-Republic-of-China

USMEF. (2012). “Australia's Cattle on Feed up Sharply; Grain-fed Exports Shift toward China, EU.” https://www.usmef.org/australias-cattle-on-feed-up-sharply-grain-fed-exports-shift-toward-china-eu/

Tian, Feng. 2017. "A Supply Chain Traceability System for Food Safety based on HACCP, Blockchain & Internet of Things." In *2017 International Conference on Service Systems and Service Management* (pp. 1–6). IEEE.

Van den Broeck, Goedele., Johan Swinnen, and Miet Maertens. 2017."Global Value Chains, Large-Scale Farming, and Poverty: Long-Term Effects in Senegal." *Food Policy* 66: 97–107.

Wang, Zhigang, Yanna Mao, and Fred Gale. 2008."Chinese Consumer Demand for Food Safety Attributes in Milk Products." *Food Policy* 33(1): 27–36.

Wang, Ying, Kevin K.F. So, and Beverley A. Sparks. 2017."Technology Readiness and Customer Satisfaction with Travel Technologies: A Cross-Country Investigation." *Journal of Travel Research* 56(5): 563–577.

Wiegard, Rouven B., and Michael H. Breitner. 2019."Smart Services in Healthcare: A Risk-Benefit-Analysis of Pay-as-You-Live Services from Customer Perspective in Germany." *Electronic Markets* 29(1): 107–123.

Yiannas, Frank. 2018."A New Era of Food Transparency Powered by Blockchain." *Innovations: Technology, Governance, Globalization* 12(1–2): 46–56.

Zulkifly, M. Mohd Faizal, Shazli E. Ghazali, Normah Che Din, Devinder K.A. Singh, and Ponnusamy Subramaniam. 2016."A Review of Risk Factors for Cognitive Impairment in Stroke Survivors." *The Scientific World Journal* 2016: 3456943.

**How to cite this article:** Lin W, Ortega DL, Ufer D, Caputo V, Awokuse T. Blockchain-based traceability and demand for U.S. beef in China. *Appl Econ Perspect Policy*. 2022;44: 253–272. https://doi.org/10.1002/aepp.13135

## APPENDIX A. INFORMATION PRESENTED TO RESPONDENTS BEFORE CHOICE TASKS

Before evaluating the choice tasks, please read the information regarding blockchain food traceability.

Blockchain is a decentralized shared, programmable, cryptographically secure, and therefore trusted ledger which no single user controls and which can be inspected by anyone. Each record on a blockchain is agreed upon by all members of the network, and then it becomes a permanent record; it cannot be altered (World Economic Forum).

The food industry has taken advantage of Blockchain technology to trace food products in its supply chain. Information is digitally connected to a food product and entered into the blockchain at every step of its journey – from farm gate to retail store. **Blockchain traceability is a novel tool compared to traditional digital traceability systems. The use of blockchain traceability would provide real-time product information, enhance transparency and trust as well as deter food fraud in the food system.**