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Impacts of the COVID-19 pandemic on consumers’ food safety knowledge and behavior in China

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Abstract
This study assesses the impacts of the COVID-19 pandemic on Chinese residents’ food safety knowledge and behavior, and explores the possible influence mechanism, namely, focus on media information. The study is based on internet survey data of 1373 residents in China. A series of econometric models are developed to estimate food safety knowledge and behavior of residents. Both the descriptive and econometric results indicate that the existence of COVID-19 cases in a community has a significantly positive effect on residents’ food safety knowledge and behavior. Residents focusing on food safety-related information tend to have higher food safety knowledge and practice food safety behavior. When controlling the variable focused on food safety-related information, the marginal effects of the existence of COVID-19 cases in a community on residents’ food safety knowledge and behavior significantly decrease. However, the decrease in consumers’ food safety knowledge is quite minor. Hence, the COVID-19 pandemic indeed improves Chinese residents’ food safety knowledge and behavior, while focus on food safety-related information is an important mechanism for improving food safety behavior. Moreover, the estimation results of the simultaneous equations model reveal that consumers’ food safety knowledge has a significant and positive effect on their food safety behavior. Heterogeneous impacts of the COVID-19 pandemic on residents’ food safety knowledge and behavior among different regions and income groups are observed. The findings of this study provide evidence that public health events could enhance residents’ safety awareness and behavior, while residents’ focus on relevant information plays an important role in improving knowledge and impacting behavior.

Keywords: food safety, knowledge, behavior, COVID-19

1. Introduction

The sudden spread of the coronavirus disease (COVID-19) pandemic in China has had extensive impacts on the socioeconomic and daily lives of residents. To slow the spread of the virus, which is mainly through person-to-person contact, the Chinese government has imposed some of the strictest community control measures since the founding of the People’s Republic of China (Fang et al. 2020; Lin et al. 2020). These measures include suspension of
intra-city public transport, closure of entertainment venues, and banning of public gatherings, which has forced people to eat out less and to increase household food handling (Tian et al. 2020).

While the original source of the COVID-19 is still unknown, some scientists consider its outbreak to be related to the consumption of wild animals, such as pangolins (Xiao et al. 2020). Some cases have been linked to the Huanan Seafood Wholesale Market at the early stage of the outbreak (Wu et al. 2020). Also, the outbreak of the COVID-19 in Beijing (June) and Dalian (July) appears to be related to the local seafood wholesale market.

In this context, food safety has become one of the public’s top concerns and has been widely discussed in various media, including television, newspapers, and the internet. The illegal trade in wild animals has been banned in China since the end of February, 2020 (Xinhua News Agency 2020). Some food safety measures have been repeatedly emphasized, including washing hands with soap and water before preparing or eating food, keeping raw meat separate from other foods, and cooking meat to the right temperature to kill harmful germs. Health authorities in several cities have suggested a change to Chinese traditional table etiquette for communal meals, that is, to use separate chopsticks and spoons for diners when transferring food from shared dishes to their own plates (Yi 2020). The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) have issued guidelines specifically for food businesses (FAO and WHO 2020).

Previous studies have shown that consumers mostly lack basic knowledge and safety strategies for home food handling, and their food safety awareness can be significantly affected by food safety incidents and public health events. Based on a consumer survey, Qiao et al. (2012) found that most consumers had a relatively low level of knowledge of the Food Safety Law, and households with children were significantly more concerned about melamine and two communicable diseases, SARS and H1N1 than were households without children. According to Jin and Han (2014), people with less knowledge are more likely to panic owing to mass media reports regarding a food hazard issue, while Liu and Ma (2016) found that the amplification effect of food scandals on citizens’ food safety concerns is more prominent among residents with higher levels of education. In addition, demographic variables have a significant impact on consumers’ food safety behavior (Byrd-Bredbenner et al. 2007; Losasso et al. 2012).

However, the impact of the COVID-19 pandemic on consumers’ food safety awareness has not been explored in the literature. Most relevant social science research has focused on the economic impact of the pandemic (Atkeson 2020; Baldwin and Mauro 2020; Barro et al. 2020; Eichenbaum et al. 2020; Gong et al. 2020; Guerrieri et al. 2020), although a few studies have investigated the response of household consumption to the pandemic (Baker et al. 2020). For instance, Wang et al. (2020) believed that the impacts of hog market supply chain disruption due to the COVID-19 were generally short-lived in China. Qing et al. (2020) found that consumers’ food consumption volume and expenditure changed during the COVID-19 pandemic.

Explore the impact of the COVID-19 pandemic on consumers’ food safety awareness would help to understand the public response of food safety to public health events. The main purpose of this study is to assess the impact of the COVID-19 pandemic on residents’ food safety knowledge and behavior in China and to explore the possible influence mechanism, namely, focus on media information. To achieve this goal, a series of econometric models are estimated by employing nationwide internet survey data of 1 373 residents. The results suggest that the shock of COVID-19 pandemic significantly affects consumers’ food safety knowledge and practice of food safety behavior, while residents’ focus on food safety-related information is a mediator variable. Furthermore, improving consumers’ food safety knowledge can significantly enhance their food safety behavior. These findings not only provide a better understanding of consumers’ food safety knowledge and behavior under the COVID-19 pandemic but also add to the literature on the impact of public health events on consumers’ food safety knowledge and behavior.

The rest of this article is organized as follows. Section 2 introduces the data used in this study and presents the econometric model. Section 3 presents the descriptive statistics results, the main empirical results, and the heterogeneity analysis results. Section 4 concludes with several policy implications.

2. Data and methods

2.1. Data source

This study is based on data from an online survey of residents during the COVID-19 outbreak in China in early March 2020. An electronic questionnaire was designed based on a free online survey platform and delivered online through WeChat and QQ groups. For each respondent, the basic characteristics of household and individuals and their food safety knowledge and behavior were collected. In addition, the data include residents’ focus on COVID-19 pandemic-related information and the existence of COVID-19 cases in their community as well as city control measures during the outbreak. After 10 days of online data collection, finally, the sample covered 1 373 residents from more than 230 cities in 31 provinces, autonomous regions.
and municipalities.

2.2. Empirical models

Following previous studies (e.g., McLeod et al. 2011; Ren et al. 2019), the Baron and Kenny’s approach is used to examine the impacts of the COVID-19 pandemic on consumers’ food safety knowledge and behavior as well as investigate the potential mechanism (Baron and Kenny 1986).

Firstly, to detect the relationship between the COVID-19 pandemic and consumers’ food safety knowledge and behavior, we start with two benchmark models (Ren et al. 2019), which can be expressed as:

\[
\begin{align*}
\text{Knowledge}_i &= \alpha_1 + \alpha_2 \times \text{Pandemic}_i + \alpha_3 \times \text{Control}_i + \epsilon_i, \quad (1) \\
\text{Behavior}_i &= \alpha_4 + \alpha_5 \times \text{Pandemic}_i + \alpha_6 \times \text{Control}_i + \epsilon_i, \quad (2)
\end{align*}
\]

where Knowledge and Behavior represent the food safety knowledge and the food safety behavior of the ith consumer, respectively. Pandemic denotes the existence of COVID-19 cases in the community of the ith consumer. Control is a vector of control variables that may affect the knowledge or behavior of the ith consumer. \(\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6\) are parameters to be estimated, where \(\alpha_1\) and \(\alpha_2\) reflect the impacts of the COVID-19 pandemic on consumers’ food safety knowledge and behavior. \(\epsilon_i\) and \(\epsilon_i'\) are error terms.

Secondly, to detect the possible impact channels of the COVID-19 pandemic on consumers’ food safety knowledge and behavior, we consider consumers’ access to food safety-related news during the pandemic prevention period as a potential channel (Mediator). Thus, we can then further measure to what extent the channel is associated with the COVID-19. The model can be given as:

\[
\text{Mediator}_i = c_1 + c_2 \times \text{Pandemic}_i + c_3 \times \text{Control}_i + \mu_i, \quad (3)
\]

where the parameter \(c_1\) indicates the change in the dependent variable when the Pandemic changes one unit.

Thirdly, after identifying the correlation between the COVID-19 pandemic and the potential channel, the mediator variable is further incorporated into the eqs. (1) and (2). Eqs. (4) and (5) are developed by further controlling potential mediator variables based on eqs. (1) and (2).

\[
\begin{align*}
\text{Knowledge}_i &= \beta_1 + \beta_2 \times \text{Pandemic}_i + \beta_3 \times \text{Mediator}_i + \lambda \times \text{Control}_i + \epsilon_i, \quad (4) \\
\text{Knowledge}_i &= \beta_1' + \beta_2' \times \text{Pandemic}_i + \lambda' \times \text{Mediator}_i + \epsilon_i', \quad (5)
\end{align*}
\]

where \(\beta_1\) and \(\beta_1'\) in eqs. (3) and (4) respectively denote the relations between the COVID-19 pandemic and consumers’ food safety knowledge and behavior after controlling for the potential mediator variables.

The significances and magnitudes of the coefficients \(\alpha_1, \alpha_2, \alpha_3, \beta_1, \beta_1',\) and \(\lambda\) in eqs. (1)–(5) can assist us to confirm the impact channels of the COVID-19 pandemic on consumers’ food safety knowledge and behavior. If \(\alpha_1, \alpha_2,\) and \(\lambda (\alpha_3',\) \(c_2,\) and \(\lambda')\) are statistically significant, these results validate the existence of the potential channel. In such situation, if the coefficient \(\beta_1 (\beta_1')\) is insignificant, this means the proposed mediator variable as an impact channel can fully explain relationship between the COVID-19 pandemic and consumers’ food safety knowledge (behavior). If the coefficient \(\beta_1 (\beta_1')\) is statistically significant, the proposed mediator variable can only partially explain (\([(\alpha_2-\beta_1)\alpha_1]%\) \([(\alpha_3-\beta_1')\alpha_1]%\)).

Furthermore, we attempt to examine whether consumers’ food safety knowledge impacts their behavior. As there may be some variables that simultaneously affect consumers’ food safety knowledge and behavior, a simultaneous equations model comprising two equations is established as follows:

\[
\begin{align*}
\text{Knowledge}_i &= \theta_1 + \theta_2 \times \text{IV}_i + \theta_3 \times \text{Control}_i + \epsilon_i, \\
\text{Behavior}_i &= \gamma_1 + \gamma_2 \times \text{Knowledge}_i + \gamma_3 \times \text{Control}_i + \epsilon_i.
\end{align*}
\]

where the parameter \(\gamma_1\) indicates the impact of consumers’ food safety knowledge on their behavior. \(IV\) is an instrumental variable that controls for the potential endogeneity of Knowledge, in explaining Behavior. Here, the vector of control variables (Control) in eq. (6) includes Pandemic, and Mediator, in addition to Control.

3. Results and discussion

3.1. Descriptive statistics

Table 1 shows the key variables used in this study. Firstly, referring the study of dietary and nutrition knowledge (Shimokawa 2013; Min et al. 2020; Zhao and Yu 2020), food safety knowledge is defined as the score of food safety knowledge based on a set of food safety-related questions (Appendix A). There are eight questions, and no respondent provides correct answers for all questions. On average, the score is only 2.6, implying there is relatively low food safety knowledge of the respondents. In terms of food safety behavior, we take the number of times per month that respondents disinfected their cutting boards as an indicator. The reason for this choice is mainly considering two aspects: 1) the hygiene situation of cutting boards is an important component of household food safety behavior and directly related to the safety of homemade food, and 2) the disinfection of cutting boards is the most convenient and easiest measure to improve household food safety. Higher frequency of cutting board disinfection represents a higher level of food safety behavior. On average, consumers disinfect their cutting boards about 13 times per month, showing a relatively high level of food safety behavior.

The explanatory variable of focus is the existence of
COVID-19 cases, which here is represented by whether there are any people with COVID-19 in a community. The survey results show that 15% of consumers were living in a community with COVID-19 cases. As for the potential mediator variables, two variables are used to denote consumers’ access to food safety-related news: 1) whether consumers pay more attention to food safety news due to the pandemic, and 2) the timeliness of obtaining food safety news in the pandemic prevention period. Table 1 suggests that 69% of consumers paid more attention to food safety news due to the COVID-19 pandemic; meanwhile, most consumers tended to access food safety news very timely.

Table 2 further presents the differences of food safety knowledge and behavior and two mediator variables between respondents living in a community with and without COVID-19 cases. The results indicate that consumers living in a community with COVID-19 cases have a higher score of food safety knowledge, disinfect their cutting boards more often per month, pay more attention to food safety news, and obtain food safety news timelier. The results imply that the COVID-19 pandemic appears to improve consumers’ food safety knowledge and behavior as well as access to food safety-related news.

Table 1 Summary of key variables in this study

| Variables | Definition and description | Mean | Std. Dev. | Min | Max |
|-----------|---------------------------|------|-----------|-----|-----|
| Knowledge | Score of food safety knowledge | 2.60 | 1.56 | 0 | 7 |
| Behavior | Number of times per month that cutting boards are disinfected | 12.90 | 12.68 | 0 | 30 |
| Pandemic  | Whether there are any COVID-19 cases in the community (1=yes; 0=otherwise) | 0.15 | 0.36 | 0 | 1 |
| News 1    | Pay more attention to food safety news than before due to the pandemic (1=yes; 0=otherwise) | 0.69 | 0.46 | 0 | 1 |
| News 2    | Timeliness of obtaining food safety news (1=very untimely; 2=untimely; 3=general; 4=timely; 5=very timely) | 4.23 | 0.89 | 1 | 5 |

COVID-19 pandemic appears to improve consumers’ food safety knowledge and behavior as well as access to food safety-related news.

The definitions and descriptive statistics of control variables used in this study are summarized in Table 3. Referring to previous studies on dietary and nutrition knowledge and behavior (Shimokawa 2013; Min et al. 2020; Zhao and Yu 2020), the control variables include the characteristics of individual and household. For example, gender, age, and education level of respondents are included and hypothesized to significantly determine consumers’ food safety knowledge and behavior. At household level, the variables that may affect consumers’ food safety knowledge and behavior consist of the number of family members, household income, and residence place. As this study focuses on the pandemic prevention period, we also control for the variable whether the residence city is locked down. The instrumental variable used in this study is regarding as the learning experience of consumers in food safety-related knowledge, which is assumed to be significantly correlated with consumers’ food safety knowledge but insignificantly correlated with consumers’ food safety behavior. The validity and exogeneity of the proposed instrumental variable are confirmed by a falsification test shown in Appendix B.

3.2. Impact of the COVID-19 pandemic on consumers’ food safety knowledge

Table 4 reports the estimation results for eqs. (1) and (3), showing the relationships between the COVID-19 pandemic and the score of consumers’ food safety knowledge, and between the COVID-19 pandemic and access to food safety-related news. While the relatively small values of $R^2$ suggest poor goodness of fit of the three empirical models, the significant values of $F$-statistic and Wald Chi² confirm the joint significance of the independent variables included. Thus, overall, the specification of the empirical models is valid.

The results of eq. (1) estimated by ordinary least squares (OLS) are reported in the second column of Table 4. The results indicate that the existence of COVID-19 cases in a community is positively correlated with consumers’ food safety knowledge, which is consistent with the findings of the descriptive statistics. A consumer living in a community with COVID-19 cases has a 0.75 higher score of food safety knowledge than those living in a community without a COVID-19 case. Moreover, some characteristic variable of individual and family significantly determine food safety knowledge. For instance, consumers aged between 18 and 25 years have a significantly lower score of food safety knowledge than do consumers in the lowest age group.
(age<18 years), while consumers aged more than 50 years have a significantly higher score. The education level of consumers appears to have a nonlinear relationship with food safety knowledge. With the increase in the education level, consumers’ score of food safety knowledge first decreases and then increases. Compared with the lowest income group, consumers in the three middle income groups have a lower score of food safety knowledge.

The third and fourth columns report the estimation results of access to food safety-related news (eq. (3)), wherein

| Table 3 | Summary of control variables used in this study |
|----------|-----------------------------------------------|
| Variables | Definition and description | Mean | Std. Dev. | Min | Max |
| Gender | Gender of respondents (1=male; 0=female) | 0.38 | 0.49 | 0 | 1 |
| Age group (years) | | | | | |
| A1 | Ages≤18 (1=yes; 0=otherwise) | 0.03 | 0.16 | 0 | 1 |
| A2 | 18<Age≤25 (1=yes; 0=otherwise) | 0.74 | 0.44 | 0 | 1 |
| A3 | 25<Age≤40 (1=yes; 0=otherwise) | 0.08 | 0.27 | 0 | 1 |
| A4 | 40<Age≤50 (1=yes; 0=otherwise) | 0.12 | 0.32 | 0 | 1 |
| A5 | Age>50 (1=yes; 0=otherwise) | 0.04 | 0.19 | 0 | 1 |
| Education | Educated years | 15.18 | 2.16 | 9 | 19 |
| Hhsize | Number of family members | 3.85 | 1.33 | 0 | 13 |
| Income group (CNY yr⁻¹) | | | | | |
| Inc1 | Income≤50 000 (1=yes; 0=otherwise) | 0.43 | 0.50 | 0 | 1 |
| Inc2 | 50 000<Income≤100 000 (1=yes; 0=otherwise) | 0.23 | 0.42 | 0 | 1 |
| Inc3 | 100 000<Income≤200 000 (1=yes; 0=otherwise) | 0.23 | 0.42 | 0 | 1 |
| Inc4 | 200 000<Income≤500 000 (1=yes; 0=otherwise) | 0.08 | 0.28 | 0 | 1 |
| Inc5 | Income>500 000 (1=yes; 0=otherwise) | 0.03 | 0.17 | 0 | 1 |
| Urban | Living in urban area (1=yes; 0=otherwise) | 0.56 | 0.50 | 0 | 1 |
| Lockdown | Lockdown city (1=yes; 0=otherwise) | 0.50 | 0.50 | 0 | 1 |
| IV-Learn | Whether learned food safety-related knowledge (1=yes; 0=otherwise) | 0.36 | 0.48 | 0 | 1 |
| Observations | 1 373 |

| Table 4 | Estimation results for eqs. (1) and (3) |
|----------|-----------------------------------------------|
| Variables | Eq. (1) | Eq. (3) |
| | Food safety knowledge | News 1 | News 2 |
| | Coef. | Robust Std. Err | Coef. | Robust Std. Err | Coef. | Robust Std. Err |
| Pandemic | 0.75** | 0.13 | 0.21** | 0.10 | 0.17 | 0.09 |
| Gender | 0.12 | 0.08 | -0.16** | 0.07 | 0.09 | 0.06 |
| Age group | | | | | | |
| A1 | | | | | | |
| A2 | -0.59** | 0.30 | -0.27 | 0.25 | -0.24 | 0.24 |
| A3 | 0.15 | 0.32 | -0.18 | 0.27 | -0.07 | 0.26 |
| A4 | 0.05 | 0.30 | 0.19 | 0.26 | 0.31 | 0.25 |
| A5 | 0.64* | 0.36 | -0.14 | 0.30 | -0.37 | 0.31 |
| Education | | | | | | |
| A2 | -0.46** | 0.21 | 0.28* | 0.16 | 0.20 | 0.15 |
| A3 | -0.12 | 0.09 | -0.09 | 0.05 | -0.01 | 0.01 |
| A4 | -0.10 | 0.03 | -0.03 | 0.03 | 0.01 | 0.01 |
| Hhsize | 0.02 | 0.03 | -0.03 | 0.03 | 0.01 | 0.01 |
| Income group | | | | | | |
| Inc1 | | | | | | |
| Inc2 | -0.50*** | 0.10 | -0.09 | -0.09 | -0.14** | 0.07 |
| Inc3 | -0.41*** | 0.11 | -0.18** | -0.10 | -0.04 | 0.08 |
| Inc4 | -0.54*** | 0.15 | -0.10 | 0.14 | 0.13 | 0.12 |
| Inc5 | 0.01 | 0.24 | -0.56** | -0.21 | -0.30 | 0.21 |
| Urban | -0.12 | 0.09 | -0.08 | 0.08 | 0.06 | 0.07 |
| Lockdown | -0.10 | 0.08 | 0.03 | 0.07 | -0.08 | 0.07 |
| Constant | 6.33*** | 1.45 | -0.94*** | | |
| F/Wald Chi² | 10.84 | 40.64 | 44.91 |
| R²/Pseudo R² | 0.126 | 0.022 | 0.015 |
| Observations | 1 373 | 1 373 | 1 373 |

1)Reference group.

**, *, and indicate significance levels at 10, 5, and 1%, respectively.
paying more attention to food safety news due to the pandemic (News 1) and obtaining food safety news timelier in the pandemic prevention period (News 2) are estimated by probit and order probit regressions, respectively. Obviously, there are significant and positive relationships between COVID-19 pandemic and access to food safety-related news, including News 1 and News 2. Hence, the results in Table 4 mean if a consumer living in a community with COVID-19 cases, she/he tends to pay more attention to food safety news due to the pandemic, obtains food safety news more timelier in the pandemic prevention period, and has a higher score of food safety knowledge than his or her counterpart.

The estimation results of OLS for eq. (4) are presented in Table 5, revealing the impact channels of the COVID-19 pandemic on food safety knowledge. By comparing the estimated parameters of the COVID-19 pandemic in eq. (1) of Table 4 and OLS (4.1), (4.2), and (4.3), this study finds that if the mediator variables are further controlled, the estimated parameters of the COVID-19 pandemic decrease. Specifically, the insignificant coefficients of News 1 in OLS (4.1) and OLS (4.3) suggest paying more attention to food safety news seems not to be an impact channel. The minor decreases in the estimated parameters of pandemic in OLS (4.2) and (4.3) as compared with that in eq. (1) of Table 4 imply that obtaining food safety news timelier in the pandemic prevention period is an impact channel of the COVID-19 pandemic on food safety knowledge, but can only explain 2.67%.

### 3.3. Impacts of the COVID-19 pandemic on consumers’ food safety behavior

The estimation results for eq. (2) in Table 6 suggest that the COVID-19 pandemic have a significant impact on consumers’ food safety behavior. First, the positive impact of the COVID-19 pandemic on the disinfection times per month of cutting boards (OLS (2) in Table 6) means that consumers who live in a community with COVID-19 cases on average disinfect their cutting boards about 3.29 times more per month than do those living in a community without a COVID-19 case. Hence, the presence of the COVID-19 pandemic in a community play a significant role in improving consumers’ food safety behavior.

As shown in Table 6, most of the control variables have no significant impacts on consumers’ food safety behavior in addition to age and income. Consumers who are between 18 and 25 years have disinfected their cutting boards significantly fewer times per month than do those in the lowest age group. In addition, consumers in the highest income group disinfect their cutting boards significantly more times per month than do those in the lowest income group. These results imply that the 18–25-year-old and poor consumers have the worst food safety behavior and need to improve.

The estimation results of eq. (5) are reported in Table 7, validating the access to food safety-related news as the impact channels of the COVID-19 pandemic on food safety behavior. By comparing OLS (2) in Table 6 with OLS (5.1) in Table 7, it is found that the estimated parameter of the pandemic decreases about 5.8% after further controlling for whether consumers pay more attention to food safety news. Similarly, the estimated parameters of the pandemic in OLS (5.2) and OLS (5.3) decrease about 7 and 9.4%, respectively, compared to that in OLS (2) of Table 6. These results prove that the impact channels of the COVID-19 pandemic on food safety behavior are whether consumers pay more attention to food safety news as well as the timeliness of obtaining food safety news.

### 3.4. Impacts of consumers’ food safety knowledge on their food safety behavior

The established simultaneous equations model (eq. (6)) is estimated using two-stage least squares (2SLS), while the estimation results are reported in Table 8. We use the learning experience in food safety-related knowledge as an instrumental variable. Intuitively, the learning experience in

| Variables | OLS (4.1) | OLS (4.2) | OLS (4.3) |
|-----------|-----------|-----------|-----------|
|           | Coef.     | Robust Std. Err | Coef. | Robust Std. Err | Coef. | Robust Std. Err |
| Pandemic  | 0.74**    | 0.13       | 0.73**  | 0.13       | 0.73**  | 0.13       |
| News 1    | 0.13      | 0.09       |         |            |         |            |
| News 2    | 0.12**    | 0.05       | 0.11**  | 0.05       |         |            |
| Control variables | Yes | 1.45 | Yes | 1.44 | Yes | 1.44 |
| Constant  | 6.30**    | 1.45       | 6.00**  | 1.44       | 6.02**  | 1.44       |
| F         | 10.33**   | 10.73**    | 10.16** | 10.16**    |         |            |
| R²        | 0.128     | 0.130      | 0.131   | 0.131      |         |            |
| Obs.      | 1373      | 1373       | 1373    | 1373       | 1373    | 1373       |

* and ** indicate significance levels at 5 and 1%, respectively.
food safety-related knowledge can affect the score of food safety knowledge, while the learning experience does not have a directly significant impact on the food safety behavior. The falsification test results in Appendix B validate the exogeneity of the instrumental variable. The $F$-statistic for the instrumental variable is 1440.52, suggesting that the instrumental variable is not weak.

The falsification test results in Appendix B validate the exogeneity of the instrumental variable. The $F$-statistic for the instrumental variable is 1440.52, suggesting that the instrumental variable is not weak.

The estimation results reveal that consumers’ food safety knowledge has a significant and positive effect on their food safety behavior. The 1-unit increase in the score of consumers’ food safety knowledge results in an increase of 0.53 more times that cutting boards are disinfected per month. Hence, enhancing consumers’ food safety knowledge could be an effective means of improving their food safety behavior.

### 3.5. Heterogeneity analysis by different areas (urban vs. rural)

Tables 9, 10, and 11 show the heterogeneity of the estimation results by residence areas (urban vs. rural). The results in Table 9 suggest that the correlations between the COVID-19 pandemic and food safety knowledge are significant in both urban and rural areas, while the estimated parameters of the pandemic between OLS (2) and OLS (4) indicate that the correlation in urban areas is much lower than that in rural areas. By comparing the estimated parameters of the pandemic between OLS (1) and OLS (2), and OLS (3) and OLS (4), it is found that obtaining food safety news timelier in the pandemic prevention period is an impact channel of the COVID-19 pandemic on consumers’ food safety knowledge in urban areas, but not for in rural areas. The possible impact channels of the COVID-19 pandemic on consumers’ food safety knowledge in rural areas needs to be investigated further.

Table 10 suggests that the impacts of the COVID-19 pandemic on food safety behavior in urban areas is much lower than that in rural areas. The changes in estimated parameters of the pandemic from OLS (1) to OLS (2), and from OLS (3) to OLS (4) further indicate that the access to food safety-related news is an impact channel of the COVID-19 pandemic on consumers’ food safety behavior in both urban and rural areas. Overall, the COVID-19 pandemic plays a more significant role in improving consumers’ food safety behavior in rural areas than that in urban areas.

Table 11 further reports the heterogeneity results of the impact of consumers’ food safety knowledge on their behavior by different areas. Interestingly, only in rural areas does consumers’ food safety knowledge have a significant and positive effect on their behavior. In urban areas, while learning experience in food safety-related knowledge

### Table 6 Estimation results for eq. (2)

| Variables      | Coef. | Robust Std. Err |
|----------------|-------|-----------------|
| Pandemic       | 3.29***| 0.98            |
| Gender         | 0.81  | 0.70            |
| Age group A1   |       |                 |
| A2             | −4.66**| 2.20            |
| A3             | −1.89  | 2.41            |
| A4             | −0.34  | 2.31            |
| A5             | −1.35  | 2.70            |
| Education      | 0.957  | 1.47            |
| Education2     | −0.05  | 0.05            |
| Hhsize         | −0.04  | 0.26            |
| Income group Inc1 |       |                 |
| Inc2           | −1.27  | 0.87            |
| Inc3           | −0.36  | 0.93            |
| Inc4           | −0.6   | 1.41            |
| Inc5           | 3.63**| 2.07            |
| Urban          | 0.821  | 0.74            |
| Lockdown       | 0.149  | 0.70            |
| Constant       | 12.85  | 9.86            |
| $F$            | 4.75***|                 |
| $R^2$          | 0.05   |                 |
| Obs.           | 1373   |                 |

1Reference group. 2, 3, *, **, and *** indicate significance levels at 10, 5, and 1%, respectively.

### Table 7 Estimation results for food safety behavior

| Variables | OLS (5.1) | Coef. | Robust Std. Err | OLS (5.2) | Coef. | Robust Std. Err | OLS (5.3) | Coef. | Robust Std. Err |
|-----------|-----------|-------|-----------------|-----------|-------|-----------------|-----------|-------|-----------------|
| Pandemic  | 3.10***   | 0.96  |                 | 3.06***   | 0.98  |                 | 2.98**    | 0.97  |                 |
| News 1    | 2.77***   | 0.72  |                 |           |       |                 |           |       |                 |
| News 2    |           |       |                 |           |       |                 | 1.77***   | 0.38  | 1.44***         |
| Control variables | Yes |       |                 | Yes |       |                 | Yes |       |                 |
| Constant  | 12.31     | 9.83  |                 | 7.95      | 9.85  | 8.51***         | 9.84      |       |                 |
| $F$       | 5.47***   | 6.21**| 6.23**          |           |       |                 |           |       |                 |
| $R^2$     | 0.06      | 0.06  | 0.07            |           |       |                 |           |       |                 |
| Obs.      | 1373      | 1373  | 1373            |           |       |                 |           |       |                 |

1 and *** indicate significance levels at 5 and 1%, respectively.
significantly improves consumers’ food safety knowledge, this knowledge does not have a significant impact on their behavior. This may be due to the generally high food safety knowledge of urban consumers with relatively low variance.

### 3.6. Heterogeneity analysis by income groups

Table 12 reports the estimation results of consumers’ food safety knowledge by different income groups. Here, we treat the sample consumers as two quantile groups based on their household income levels (first row in Table 12). While the COVID-19 pandemic has significant and positive effects on consumers’ food safety knowledge in both income groups, the impact extent of the COVID-19 pandemic on consumers’ food safety knowledge is relatively large for the low-income group. For both the low- and high-income groups, the two mediator variables appear to be an impact channel of the COVID-19 pandemic on consumers’ food safety knowledge, but especially for the high-income group.

The heterogeneity results of consumers’ food safety behavior by different income groups are presented in Table 13. Like the results in Table 12, the COVID-19 pandemic has a relatively large impact on consumers’ food safety behavior for the low-income group. As the impact of the COVID-19 pandemic is insignificant for the high-income group, the access to food safety-related knowledge is only the impact channel of the COVID-19 pandemic on low-income consumers’ food safety behavior.

Table 14 reports the heterogeneity results of the simultaneous equations model of food safety knowledge and behavior by different income groups. While the learning experience of food safety-related knowledge has significant and positive effects on both low- and high-income consumers, the COVID-19 pandemic has a relatively large impact on consumers’ food safety behavior for the low-income group. As the impact of the COVID-19 pandemic is insignificant for the high-income group, the access to food safety-related knowledge is only the impact channel of the COVID-19 pandemic on low-income consumers’ food safety behavior.

### Table 8

| Variables | Knowledge Coef. | Std. Err | Behavior Coef. | Std. Err |
|-----------|-----------------|----------|----------------|----------|
| Knowledge | 0.53*           | 0.32     | 0.32           | 0.08     |
| Pandemic  | 0.05            | 0.06     | 0.07           | 0.03     |
| News 1    | 0.09*           | 0.03     | 0.41           | 0.00     |
| IV-Learn  | 2.25***         | 0.06     |                |          |
| Control   | Yes             | Yes      |                |          |
| Constant  | 4.14***         | 0.84     | 10.32          | 0.29     |
| F         | 103.35***       | 5.66***  |                |          |
| R²        | 0.58            | 0.07     |                |          |
| Obs.      | 1373            | 1373     |                |          |

*, **, and *** indicate significance levels at 10, 5, and 1%, respectively.

### Table 9

| Variables | OLS (1) Coef. | Robust Std. Err | OLS (2) Coef. | Robust Std. Err | OLS (3) Coef. | Robust Std. Err | OLS (4) Coef. | Robust Std. Err |
|-----------|---------------|-----------------|---------------|-----------------|---------------|-----------------|---------------|-----------------|
| Pandemic  | 0.49***       | 0.16            | 0.47***       | 0.16            | 1.15***       | 0.23            | 1.15***       | 0.23            |
| News 1    | 0.08          | 0.13            | 0.07          | 0.07            | 0.04          | 0.15            | 0.03          | 0.08            |
| F         | 4.77***       | 2.27            | 4.34***       | 2.24            | 5.29          | 10.32           | 5.29          | 10.32           |
| R²        | 0.09          | 0.1             | 0.2           | 0.2             | 0.2           | 0.2             | 0.2           | 0.2             |
| Obs.      | 768           | 768             | 605           | 605             | 605           | 605             | 605           | 605             |

*, **, and *** indicate significance levels at 5 and 1%, respectively.

### Table 10

| Variables | OLS (1) Coef. | Robust Std. Err | OLS (2) Coef. | Robust Std. Err | OLS (3) Coef. | Robust Std. Err | OLS (4) Coef. | Robust Std. Err |
|-----------|---------------|-----------------|---------------|-----------------|---------------|-----------------|---------------|-----------------|
| Pandemic  | 2.02          | 1.24            | 1.83          | 1.26            | 5.21***       | 1.54            | 4.70***       | 1.51            |
| News 1    | 1.07          | 1.06            | 1.09          | 0.54            | 2.66**         | 1.16            | 1.83***       | 0.61            |
| F         | 3.45**         | 3.70***         | 2.28**        | 3.76**          | 5.29          | 10.32           | 6.90          | 13.95           |
| R²        | 0.06          | 0.07            | 0.05          | 0.09            | 0.05          | 0.09            | 0.09          | 0.09            |
| Obs.      | 768           | 768             | 605           | 605             | 605           | 605             | 605           | 605             |

*, **, and *** indicate significance levels at 10, 5, and 1%, respectively.
consumers’ food safety behavior, the impact of food safety knowledge on food safety behavior is significant only for the low-income group.

### 4. Conclusion

With the spread of the COVID-19 pandemic in China, food safety-related issues have received widespread attention. Under such circumstances, the COVID-19 pandemic may change consumers’ food safety knowledge and behavior. Based on internet survey data of 1,373 residents in China, this study assesses the impact of the COVID-19 pandemic on residents’ food safety knowledge and behavior and explores a possible influence mechanism, namely, focus on media information. The results of descriptive statistics show relatively low food safety knowledge yet a relatively high level of food safety behavior of Chinese consumers. Consumers living in communities with COVID-19 cases...
have higher food safety knowledge scores, disinfect cutting boards more per month, pay more attention to food safety information, and more timely access to food safety news.

The econometric results further indicate that the existence of COVID-19 cases in a located community has a significantly positive effect on residents’ food safety knowledge and behavior. Residents who focus on COVID-19 pandemic-related information tend to have higher food safety knowledge and practice food safety behavior. When controlling for the variable of focus on COVID-19 pandemic-related information, the marginal effects of the existence of COVID-19 cases in a community on residents’ food safety knowledge and behavior decrease significantly. However, the decrease on consumers’ food safety knowledge is quite small. Hence, the COVID-19 pandemic indeed improves Chinese residents’ food safety knowledge and behavior over time cannot be observed. Therefore, it is suggested that follow-up research should employ panel data when researching related issues in the future.

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Appendices associated with this paper can be available on
http://www.ChinaAgriSci.com/V2/En/appendix.htm

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### Table 14 Heterogeneity analysis for the simultaneous estimation of food safety knowledge and behavior by income groups

| Variables | Low (Income≤50,000 CNY yr⁻¹) | High (Income>50,000 CNY yr⁻¹) |
|-----------|-------------------------------|-------------------------------|
|           | Knowledge                     | Behavior                      | Knowledge                     | Behavior                      |
|           | Coef. Std. Err                | Coef. Std. Err                | Coef. Std. Err                | Coef. Std. Err                |
| Knowledge | 0.85 0.45                     | 0.24 0.45                     | 0.50 *** 0.14                 | 3.95 *** 1.47                 |
| Pandemic  | 0.02 0.11                     | 0.06 0.08                     | 0.07 0.06                     | 1.16 0.61                     |
| News 1    | 0.07 0.06                     | 0.10 0.29                     | 2.29 *** 0.10                 | 1.07 0.29                     |
| News 2    | 2.29 *** 0.10                 | 2.21 *** 0.55                 | 5.29 *** 1.41                 | 15.17                        |
| Control variables | Yes | Yes | 3.70 *** | 1.09 |
| Constant  | 48.77 *** 5.51 ***            | 81.49 *** 2.52 ***           |
| F         | 0.54 0.11                     | 0.11 0.598                   | 0.54 0.11                     | 0.04 1.04                    |
| R²        | 591 591                       | 782 782                      | 591 591                       | 782 782                      |

The results of this study have important implications for policymakers and the catering industry in China. The government should use public health events to improve public knowledge of food safety and to change unhealthy eating habits. In addition, timely release of food safety information during public health events is necessary to reduce consumer panic and to increase consumer food safety awareness.

Finally, this study has some limitations. First, since the data cannot observe the food safety knowledge and behavior of consumers who are not online, the results may be biased to some extent. However, considering the number of internet users in China has reached 854 million, the online survey is still representative, especially during the pandemic, when the number of internet users and the time they spend online have increased dramatically due to strict community control measures. Moreover, this study uses cross-sectional data, and thus, the change of consumers’ food safety knowledge and behavior over time cannot be observed. Therefore, it is suggested that follow-up research should employ panel data when researching related issues in the future.
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