The Impact of COVID-19 on the Dietary Diversity of Children and Adolescents: Evidence from a Rural/Urban Panel Study

Yi Cui, Wei Si, Qiran Zhao, Thomas Glauben, Xiaolong Feng*

Abstract

This paper offers the first empirical evidence of the impact of COVID-19 on dietary diversity among children and adolescents in urban and rural families by using panel data collected in 2019 (before COVID-19) and 2020 (during COVID-19) in northern China. Our study uses panel data from 2,201 primary school students and 1,341 junior high-school students to apply the difference in differences (DID) method to estimate the impact of COVID-19 on dietary diversity among students in urban and rural families. We found that the dietary diversity score (DDS) of rural students decreased by 0.295 points (p < 0.01) compared with that of urban students during COVID-19. Specifically, COVID-19 significantly reduced the frequency of rural students’ consumption of vegetables by 1.8 percent, protein-rich foods such as soybean products and nuts by 6.0 percent, meats by 4.0 percent, aquatic products by 6.7 percent, and eggs by 5.3 percent, compared with urban students. Further, COVID-19 had a significant negative effect on the dietary diversity of students from low- and middle-income groups, with the DDS of the low-income group decreasing by 0.31 points (p < 0.01) and that of the middle-income group by 0.12 points (p < 0.1).

Keywords: COVID-19, dietary diversity, urban and rural differences

JEL codes: I00, I14, J13, O18

I. Introduction

The COVID-19 pandemic poses a huge challenge to the world, especially with regard to food supplies and health systems (Bong et al., 2020; Mussell et al., 2020). According to
a World Health Organization report on COVID-19 (WHO, 2021), as of October 3, 2021, COVID-19 had resulted in more than 23.5 million laboratory-confirmed infections and 4.7 million deaths. China has significantly curbed the pandemic – largely due to the government, which adopted a series of strict domestic quarantine policies to control the spread of COVID-19 (Fang et al., 2020; Kong et al., 2020; Liu et al., 2020a). These policies included blockades, trade restrictions, closure of public spaces, and encouraging people to stay at home. These policies also affected the food system by disrupting the production, transportation, and sale of nutritious, fresh, and affordable foods (Fore et al., 2020; Mussell et al., 2020). Some policies influenced social and physical activities, such as limited social contact, increased physical distance, the cancellation or postponing of large public events, and the closure of schools, cinemas, and museums (Chen et al., 2020). The policies affected food supplies and aggravated the lack of food nutrition, the lack of dietary diversity, and health risks.

People’s dietary behaviors have been transformed by COVID-19 (Zhang et al., 2020). The pandemic has caused disruptions in the agri-food supply chain, which has exacerbated difficulties in bringing fresh food to the market (Mussell et al., 2020) owing to the restrictions on transportation and the lack of a sufficient labor force (Mussell et al., 2020; Zhao et al., 2020), which has increased the difficulty experienced by people in acquiring various types of food. Many countries, including China, reported finding traces of the virus on packages of frozen food in the market (Fisher et al., 2020; Liu et al., 2020b). Markets removed such frozen foods and suspended imports of frozen seafood (Fisher et al., 2020). Consequently, Chinese residents spontaneously reduced their intake of raw and frozen food (Zhang et al., 2020), which impaired nutritious food accessibility. Strict prevention measures, such as quarantine at home or closure of restaurants, also posed a potential barrier to accessing a variety of foods (Zhao et al., 2020). Meanwhile, some studies found that when a stressful situation arises, such as the COVID-19 pandemic, people often experience emotional changes that may subsequently lead to modification of dietary behaviors such as seeking relief by eating sweet food, fried chicken, or hamburgers (Cecchetto et al., 2021; Mason et al., 2021).

Furthermore, public health emergencies such as the outbreaks of Ebola (Ji et al., 2017) and severe acute respiratory syndrome (Lee et al., 2006) can cause public mental health problems. Coronavirus disease 2019 has also led to global anxiety and depression due to disrupted travel plans, social isolation, media information overload, and panic buying of necessary goods (Ho et al., 2020). The anxiety associated with COVID-19 could cause public physical health problems through its impact on people’s dietary behaviors and reduced physical activity (Leddy et al., 2020; Zhang et al., 2020). The pandemic has affected people’s usual physical activity and sedentary behavior...
The Impact of COVID-19 on the Dietary Diversity of Children and Adolescents

(Cheval et al., 2021). Lockdown measures, including gym closure, public movement restriction, and reduced commuting, have dramatically disrupted daily routines. Meanwhile, people’s stress and anxiety emerging from the risk of contracting the virus may reduce their inclination to leave their houses to perform their usual activities, reducing physical activity and increasing sedentary behavior (Cheval et al., 2021).

COVID-19 poses a special threat to the nutritional status and health of children and adolescents (Headey et al., 2020). Strict epidemic control policies, declining household incomes, and changes in the availability and affordability of nutritious food have impaired dietary diversity in children and adolescents (Carroll et al., 2020; Headey et al., 2020). On the one hand, a series of strict pandemic prevention and control measures (such as strict home quarantine, traffic control, and shop closure) made it difficult for families to buy nutritious food and changed the availability of nutritious food. On the other hand, the decreased family income affected by the pandemic has reduced the affordability of nutritious food. Moreover, school-age children who suffer from infectious diseases can bring anxiety, depression, and other mental health problems because of their underdeveloped emotional reactions and coping techniques (Köhler-Forsberg et al., 2019; Golberstein et al., 2020). The ongoing epidemic forces children and adolescents to maintain a social distance and limit communication with friends, which can lead to stress and anxiety. The disease and containment measures can have a negative impact on children’s mental health (Qiu et al., 2020); however, some studies have reported conflicting findings. Several studies have reported that there is a possibility that closer contact with family members and more home cooking could improve children’s knowledge about nutrition and related behaviors (Simmons and Chapman, 2012; Fulkerson et al., 2018). For this reason, along with strict quarantine at home or closure of restaurants, COVID-19 may have a positive impact on children’s dietary diversity and physical health. A balanced and varied diet can provide adequate nutrition for children, which is essential to maintain a normal immune system and ensure healthy growth (Calder et al., 2020). No consistent conclusion can be drawn from current research on the impact of COVID-19 on the dietary diversity of children and adolescents, however. It is therefore necessary to carry out relevant research to explore this. Specifically, children and adolescents from low-income families are facing greater risks of malnutrition than those from high-income families (Casey et al., 2001). There are a few studies on the effects of COVID-19 on children from low-income families, such as rural children. Most studies have used cross-sectional data after the pandemic outbreak, which failed to control individual and household characteristics before the outbreak, resulting in endogeneity problems.
Our study adds to the literature in three ways. First, as far as we are aware, this study offers the first empirical evidence of the impact of COVID-19 on dietary diversity among Chinese children and adolescents. Second, this study focuses on children and adolescents from urban and rural families, and further compares whether there are differences in the impact of COVID-19 on the dietary diversity among urban and rural families. Finally, two rounds of data collection were employed, covering children and adolescents before and after COVID-19, which allowed us to control for individual characteristics before the COVID-19 outbreak, solving the endogeneity problem to some extent.

The remainder of this paper is organized as follows. Section II describes the data and the method underlying the estimation of the COVID-19 impact on dietary diversity among children and adolescents in urban and rural areas. Section III presents and discusses the findings. Finally, Section IV concludes the study.

II. Data and methodology

To examine the impact of COVID-19 on the dietary diversity and health of children and adolescents, we conducted two surveys: a baseline survey in November 2019 and a follow-up survey in November 2020. In the following subsections, we will discuss the study’s sampling protocol, data-collection process, sample characteristics, and methodology.

1. Sampling

The data used in this study were obtained from a survey of all junior and primary schools in Jining district, Ulanqab, Inner Mongolia Autonomous Region, China. Jining, located in the middle of Ulanqab, is a transportation hub that attracts rural migrant laborers from nearby areas to work there, which gave us an opportunity to compare children and adolescents from urban families and rural families in the same school circumstances. The samples were collected using a stratified random sampling procedure. The project team obtained a list of junior high and primary schools in Jining from the district’s Bureau of Education. Based on this, we called the principal of each school to confirm the survey date. All the junior high and primary schools participated in the survey. The project team randomly chose two fourth-grade classes and one fifth-grade class in each primary school and randomly chose two seventh-grade classes and one eighth-grade class in each junior high school. As the project team plans to conduct a 3-year follow-up survey in this region of China, we selected more classes in the lower grades of each education stage to ensure that a large proportion of samples could be
followed up. We investigated all the students in the selected classes, and a total of 104 classes were selected.

The research team conducted two surveys in 36 sample schools. A baseline survey was conducted in November 2019 before the COVID-19 outbreak, and the project team conducted a follow-up survey in November 2020 after the outbreak. In the first round, 3,677 students completed the survey. Questionnaire information included students’ height and weight measurement, the dietary diversity scale, the depression scale, and basic individual and household questionnaire information. In the second round, 3,542 students were successfully tracked (attrition rate was 4 percent). Nearly half of the sample students (48 percent) in the sample schools came from rural families and lived with their migrant parents in urban areas (Jining district). This allowed us to compare whether COVID-19 had a different impact on children and adolescents from urban and rural families in nearly the same school environment.

2. Data collection

The two surveys included two main parts. Students completed a 24-hour dietary recall scale and questionnaires involving personal and family information.

In the first part of the survey, each student filled out a 24-hour dietary diversity recall scale on the frequency of consumption of 33 food items. Based on the 24-hour dietary recall scale, we constructed a dietary diversity score (DDS) by counting the number of food categories to measure dietary diversity following the guidelines provided by the Food and Agriculture Organization of the United Nations (FAO) (Kennedy et al., 2013). The DDS has been shown to be positively related to school-aged children’s nutrient adequacy status (Steyn et al., 2006; Kennedy et al., 2007). The standard FAO guidelines entail 14 food categories (column (1), Table 1), but to fit Chinese eating habits, we modified the algorithm by combining six categories into three larger ones (e.g. we combined “vitamin A-rich vegetables,” “dark green leafy vegetables,” and “other vegetables” into “vegetables”), replacing two categories with their local counterparts (e.g. we replaced “legumes” with “soybean products”), and dropping one category (“oil and fat”) from the FAO list. The DDS was based on nine diverse food groups. Columns (2) and (3) of Table 1 show the detailed food classifications and food items in each group. The DDS is calculated by counting the number of food groups that a student consumed in breakfast, lunch, dinner, and extra meals over the past 24 hours without considering the minimum quantity requirement for any food category. Any individual food item in each food category consumed by a student earns one point for the student’s DDS, but different individual food items consumed in the same group are not counted repeatedly. A DDS can therefore range from 0 to 9.
Table 1. Comparisons of food categories involved in definitions of the dietary diversity score (DDS)

| Food categories in the FAO guidelines | Food groups used to construct the DDS | Food items                                                                 |
|---------------------------------------|---------------------------------------|-----------------------------------------------------------------------------|
| Grains                                | Grains                                | Rice; wheat-based food (such as bread, noodles); coarse cereals (such as corn, sorghum, millet, etc.); beans (such as mung beans and black soya beans) |
| Vitamin A-rich tubers; white tubers   | Tubers                                | Potato, yam, or taro; sweet potato or purple potato                          |
| Vitamin A-rich vegetables; dark green leafy vegetables; other vegetables | Vegetables                            | Light vegetables: light leafy vegetables (such as Chinese cabbage, cabbage, etc.); eggplant; bean sprouts; cauliflower; zucchini, cucumber, or wax gourd; white or green radish; other light vegetables. Dark vegetables: dark leafy vegetables (such as spinach, chives, celery, etc.); broccoli; pepper (such as red, green, sweet peppers); fresh beans; carrots; tomato; pumpkins; other dark vegetables |
| Vitamin A-rich fruit; other fruit     | Fruit                                 | Apples, bananas, or strawberries                                            |
| Flesh meat; organ meat                | Meats                                 | Beef or lamb; pork; chicken, duck, or other poultry meat; other meat         |
| Eggs                                  | Eggs                                  | Eggs, duck eggs, or other eggs                                              |
| Fish and sea food                     | Aquatic products                      | Fish, shellfish, shrimp, etc.                                               |
| Legumes, nuts, and seeds              | Soybean products, nuts, and seeds     | Soybeans; soybean products (such as soy milk, tofu); nuts (such as peanuts, seeds, cashews, walnuts, etc.) |
| Milk and milk products                | Milk and milk products                | Milk, yogurt, or other milk products                                       |
| Oil and fat                           | /                                     | /                                                                           |

Source: Kennedy et al. (2013).

Notes: Given data limitations and local conditions, we combined “vitamin A-rich vegetables,” “dark green leafy vegetables,” and “other vegetables” into “vegetables;” we also combined “vitamin A-rich tubers” and “white tubers” into “tubers;” we combined “flesh meat” and “organ meat” into “meats;” we replaced “legumes” with “soybean products” and we dropped the “oil and fat” group.

In the second part of the survey, students and their caregivers independently completed a questionnaire that included personal and family information. The information included student personal characteristics (such as each student’s gender, age, whether the student was boarding at school, and whether the student was of a minority nationality) and household characteristics (such as the number of children, parental age, parental education level, and annual household income).

3. Sample characteristics

Table 2 reports the summary statistics of the sample students’ dietary diversity outcomes. The average DDS of the sample students with three meals is 6.65, and that with three meals plus extra meals is 7.42, indicating that the sample students ate a variety of foods. The DDS of three meals with extra meals is 0.77 higher than that of three meals.
Specifically, more fruit and milk products are consumed by children and adolescents in extra meals. Extra meals play an important role in the measurement of dietary diversity. Bi et al. (2019) analyzed 1,328 preschool children in Chinese rural area and found the mean DDS of three meals among the sample children was 5.77. Our study uses three meals with extra meals to calculate the DDS, and that is the reason why the DDS figures in our study are higher than in other studies.

| Variable                | Definition                                                                 | Observations | Three meals | Three and extra meals |
|-------------------------|---------------------------------------------------------------------------|--------------|-------------|-----------------------|
| Dietary diversity scores| The potential score range is 0–9                                          | 3,542        | 6.65        | 7.42                  |
| Grains                  | 1 = consumed over the past 24 hours; 0 = not consumed over the past 24 hours| 3,542        | 0.98        | 0.98                  |
| Tubers                  | 1 = consumed over the past 24 hours; 0 = not consumed over the past 24 hours| 3,542        | 0.79        | 0.84                  |
| Vegetables              | 1 = consumed over the past 24 hours; 0 = not consumed over the past 24 hours| 3,542        | 0.97        | 0.97                  |
| Fruit                   | 1 = consumed over the past 24 hours; 0 = not consumed over the past 24 hours| 3,542        | 0.57        | 0.89                  |
| Meats                   | 1 = consumed over the past 24 hours; 0 = not consumed over the past 24 hours| 3,542        | 0.87        | 0.88                  |
| Eggs                    | 1 = consumed over the past 24 hours; 0 = not consumed over the past 24 hours| 3,542        | 0.71        | 0.76                  |
| Aquatic                 | 1 = consumed over the past 24 hours; 0 = not consumed over the past 24 hours| 3,542        | 0.43        | 0.47                  |
| Soybean products and nuts| 1 = consumed over the past 24 hours; 0 = not consumed over the past 24 hours| 3,542        | 0.76        | 0.82                  |
| Milk and milk products  | 1 = consumed over the past 24 hours; 0 = not consumed over the past 24 hours| 3,542        | 0.59        | 0.80                  |

Source: Calculated by the authors based on data collected in the 2019 survey wave.

Table 3 reports the sample students’ personal and household characteristics. Nearly half of the students (48 percent) were rural hukou (students with permanent rural residential registration status), which provided an opportunity to study whether there...
was a difference in the impact of COVID-19 on dietary diversity between urban and rural students. We divided the sample into three household income groups based on their household income in 2019, with the median income of low-income households being RMB12,000, that of middle-income households being RMB21,000, and that of high-income households being RMB31,320.

Table 3. Variable summary statistics of children, parents, and households, 2019

| Variable                        | Definition                                                                 | Observations | Mean   | Standard deviation |
|---------------------------------|---------------------------------------------------------------------------|--------------|--------|--------------------|
| Child characteristics:          |                                                                           |              |        |                    |
| Rural                           | 1 = rural; 0 = urban                                                      | 3,542        | 0.48   | 0.50               |
| Male                            | 1 = male; 0 = female                                                      | 3,542        | 0.48   | 0.50               |
| Ethnic minority                 | 1 = ethnic minorities; 0 = Han                                            | 3,542        | 0.10   | 0.30               |
| Age                             | Age measured by year                                                      | 3,542        | 11.45  | 1.56               |
| Board                           | 1 = boards at school; 0 = does not board at school                        | 3,542        | 0.29   | 0.45               |
| Only child                      | 1 = only child; 0 = not an only child                                      | 3,542        | 0.35   | 0.48               |
| Parent and household characteristics: |                                                                           |              |        |                    |
| Father’s age                    | Age of father                                                            | 3,542        | 41.23  | 5.611              |
| Father’s education              | Educational years of father                                              | 3,542        | 10.38  | 3.253              |
| Mother’s age                    | Age of mother                                                            | 3,542        | 39.04  | 5.323              |
| Mother’s education              | Educational years of mother                                              | 3,542        | 9.85   | 3.628              |
| Log household income            | Log of annual household income                                           | 3,542        | 11.17  | 0.564              |
| Low-household income            | Per capita income is in the last third of the sample                      | 1,167        | 12,000 | 32.95              |
| Middle household income         | Per capita income is in the middle third of the sample                   | 1,217        | 21,000 | 34.36              |
| High household income           | Per capita income is in the top third of the sample                      | 1,158        | 31,320 | 32.69              |

Source: Calculated by the authors based on data collected in the 2019 wave.

Table 4 presents the differences in dietary diversity variables before and after COVID-19. Our results show that the DDS is 0.09 points lower for 2020 than it is for 2019 ($p < 0.01$), indicating a trend of decreasing dietary diversity among children and adolescents after the COVID-19 outbreak. Specifically, the probability of consumption of protein-rich foods was significantly lower than that in 2019. For example, consumption of aquatic products was reduced by 7 percent ($p < 0.01$). Meanwhile, consumption of soybean products and nuts was reduced by 2 percent.
The Impact of COVID-19 on the Dietary Diversity of Children and Adolescents

(p < 0.01) in 2020, and of milk and milk products by 2 percent (p < 0.1). On the one hand, this may be because people were worried about frozen aquatic products carrying a virus, which reduced the intake of raw and frozen food spontaneously (Zhang et al., 2020). On the other hand, high prices for protein-rich foods and income constraints may reduce the consumption of such foods (Yu et al., 2020; Dou et al., 2021).

Table 4. Comparison of dietary diversity variables, 2019 and 2020

| Outcomes                  | Observations | 2019          | 2020          | 2020 − 2019 |
|---------------------------|--------------|---------------|---------------|-------------|
|                           | Mean         | Standard deviation | Mean         | Standard deviation | Mean difference |
| Dietary diversity scores  | 3,542        | 7.42          | 1.72          | 7.33         | 1.68        | −0.09***       |
| Grains                    | 3,542        | 0.98          | 0.14          | 0.98         | 0.16        | −0.01          |
| Tubers                    | 3,542        | 0.84          | 0.37          | 0.84         | 0.37        | 0.00           |
| Vegetables                | 3,542        | 0.97          | 0.16          | 0.98         | 0.16        | 0.00           |
| Fruit                     | 3,542        | 0.89          | 0.31          | 0.89         | 0.31        | 0.00           |
| Meats                     | 3,542        | 0.88          | 0.32          | 0.88         | 0.32        | 0.00           |
| Eggs                      | 3,542        | 0.76          | 0.43          | 0.75         | 0.43        | −0.01          |
| Aquatic products          | 3,542        | 0.47          | 0.50          | 0.40         | 0.49        | −0.07***       |
| Soybean products and nuts | 3,542        | 0.82          | 0.39          | 0.79         | 0.40        | −0.02***       |
| Milk and milk products    | 3,542        | 0.80          | 0.40          | 0.82         | 0.38        | −0.02*         |

Notes: *** and * represent significance at the 1 and 10 percent levels, respectively. The significance of the mean difference between 2020 and 2019 is based on a χ² test analysis.

Table 5 presents the dietary diversity outcomes for the different income groups before and after COVID-19. Our results show that the DDS is 0.31 points (p < 0.01) and 0.12 points lower for 2020 than it is for 2019 for the low-income group and the middle-income group, respectively. However, the DDS is 0.15 points (p < 0.1) higher for 2020 than it is for 2019 in the high-income group. This indicates that COVID-19 had a negative effect on the dietary diversity of low- and middle-income households (especially on the former), which reduced their intake of protein-rich foods, such as meats, eggs, aquatic products, soybean products and nuts, milk, and milk products. The food consumption and dietary diversity of low-income households are more vulnerable to COVID-19, possibly because the pandemic reduced food availability and affordability for these households. Our findings are consistent with studies conducted in Uganda, Kenya, and India (Harris et al., 2020; Kansiime et al., 2021). The income-grouping
method included a high proportion of rural families in the low-income sample, while the rural proportion of high-income families was low, so we divided the rural and urban samples using the same threshold according to household income in 2019 and combined the urban and rural low-income groups into a low-income group, the urban and rural middle-income groups into a middle-income group, and the urban and rural high-income groups into a high-income group. We present the dietary diversity outcomes before and after COVID-19 using this income grouping method in Appendix A.

| Variable                  | Low-income group | Middle-income group | High-income group |
|---------------------------|------------------|--------------------|-------------------|
|                           | 2019  | 2020  | 2020 − 2019 | 2019  | 2020  | 2020 − 2019 | 2019  | 2020  | 2020 − 2019 |
| Dietary diversity scores  | 7.44  | 7.13  | −0.31***   | 7.40  | 7.28  | −0.12       | 7.43  | 7.58  | 0.15*       |
| Grains                    | 0.98  | 0.97  | −0.01*     | 0.99  | 0.98  | −0.01       | 0.97  | 0.98  | 0.01       |
| Tubers                    | 0.86  | 0.85  | −0.01      | 0.83  | 0.83  | 0.00        | 0.82  | 0.83  | 0.01       |
| Vegetables                | 0.98  | 0.97  | −0.01      | 0.97  | 0.98  | 0.01        | 0.97  | 0.98  | 0.01       |
| Fruit                     | 0.88  | 0.87  | −0.01      | 0.89  | 0.87  | −0.02*      | 0.91  | 0.94  | 0.03**     |
| Meats                     | 0.90  | 0.86  | −0.04***   | 0.88  | 0.88  | 0.00        | 0.88  | 0.90  | 0.02**     |
| Eggs                      | 0.76  | 0.71  | −0.05***   | 0.76  | 0.75  | −0.01       | 0.76  | 0.79  | 0.03*      |
| Aquatic products          | 0.47  | 0.35  | −0.12***   | 0.47  | 0.39  | −0.08***    | 0.48  | 0.47  | −0.01      |
| Soybean products and nuts | 0.84  | 0.76  | −0.08***   | 0.81  | 0.79  | −0.02       | 0.81  | 0.83  | 0.02       |
| Milk and milk products    | 0.78  | 0.79  | 0.01       | 0.81  | 0.81  | 0.00        | 0.82  | 0.87  | 0.05***    |

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. The significance of the mean difference between 2020 and 2019 is based on a $\chi^2$ test analysis.

4. Model

We used the difference in difference (DID) method to compare the difference between the dietary diversity of rural and urban students before and after COVID-19. Our primary specification using two-way fixed effects (child and time fixed effects) can account for time-invariant observed and unobserved confounding factors. To implement this approach, we estimate variants of the following regression (Equation (1)):

$$
outcome_{it} = \alpha + \beta_1rural + \beta_2year + \beta_3rural \times year + \gamma X_{it} + \epsilon_{it},
$$

where $outcome_{it}$ is the dietary diversity variable for student $i$ in survey wave $t$; $rural$ is a dummy variable equal to 1 if the child is a rural hukou (a person with permanent rural residential registration status); $year$ is a dummy variable equal to 1 representing 2020 (after the COVID-19 outbreak) or 0 representing 2019 (before the COVID-19 outbreak). $X_{it}$ is a vector of control variables that includes the characteristics of students and their households, such as gender, grade, boarding status, assets, parents’ educational level, and number of siblings; $\epsilon_{it}$ is an error term.
III. Results and discussion

1. Difference in the dietary diversity score between urban and rural students before and after COVID-19

Table 6 shows the results of a $\chi^2$ test to identify the difference in the DDS between urban and rural students in two survey waves. In the last column, we conducted a DID to compare the difference in DDS between urban and rural students over the two years. As shown in Table 6, before the COVID-19 outbreak (2019), the DDS of urban students is 0.05 points lower than that of rural students ($p < 0.1$). After the outbreak (2020), the DDS of urban students was 0.25 points higher than that of rural students ($p < 0.01$), and the difference in the DDS between urban and rural students increased by 0.3 points ($p < 0.01$). The differences are in the consumption of vegetables ($-0.01, p < 0.05$) and protein-rich foods (meats, eggs, aquatic products, soybean products, and nuts) over the past 24 hours.

### Table 6. Comparison of dietary diversity variables between urban and rural students before and after COVID-19

| Outcomes                     | 2019          | 2020          | (5) − (6)          |
|------------------------------|---------------|---------------|-------------------|
|                              | Urban Rural   | Urban−rural   | Urban Rural       | Urban−rural       | Mean difference |
| Dietary diversity scores     | 7.39 7.45 −0.05* | 7.45 7.20 0.25*** | −0.30***          |
| Grains                       | 0.98 0.98 0.00 | 0.98 0.97 0.00 | 0.98 0.97 0.00    | 0.01              |
| Tubers                       | 0.82 0.85 −0.03** | 0.83 0.84 −0.01 | 0.83 0.84 −0.01   | −0.02             |
| Vegetables                   | 0.97 0.98 −0.01*** | 0.98 0.97 0.01 | 0.98 0.97 0.01    | −0.01**           |
| Fruit                        | 0.90 0.89 0.02 | 0.91 0.87 0.04*** | 0.91 0.87 0.04*** | −0.02             |
| Meats                        | 0.87 0.90 −0.02** | 0.89 0.87 0.02 | 0.89 0.87 0.02    | −0.04**           |
| Eggs                         | 0.75 0.76 −0.01 | 0.77 0.73 0.05*** | 0.77 0.73 0.05*** | −0.05**           |
| Aquatic products             | 0.46 0.49 −0.03 | 0.42 0.38 0.04*** | 0.42 0.38 0.04*** | −0.07***          |
| Soybean products and nuts    | 0.81 0.83 −0.02 | 0.82 0.77 0.05*** | 0.82 0.77 0.05*** | −0.06***          |
| Milk and milk products       | 0.82 0.78 0.04*** | 0.85 0.79 0.05*** | 0.85 0.79 0.05*** | −0.01             |

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively.

2. Fixed-effect results for dietary diversity

Table 7 shows two-way fixed-effects estimates of the impact of COVID-19 on dietary diversity outcomes. We found that COVID-19 had a negative effect on the diet diversity of rural students by 0.295 ($p < 0.01$) compared with urban students, after controlling for students’ personal characteristics and household characteristics. Specifically, COVID-19 significantly reduced the probability of rural students consuming vegetables ($-1.8$ percent, $p < 0.05$), meats ($-4.0$ percent, $p < 0.05$), eggs ($-5.3$ percent, $p < 0.1$), aquatic products ($-6.7$ percent, $p < 0.1$), and soybean products and nuts ($-6.0$ percent, $p < 0.01$). Our finding is essentially consistent with a study regarding dietary diversity among Chinese residents during COVID-19, which found relatively low consumption...
of fish and legumes (Zhao et al., 2020). However, this is in contrast with a study of adolescents in Italy, Spain, Chile, Colombia, and Brazil, which found that legumes, vegetables, and fruit intake significantly increased during COVID-19 (Ruiz-Roso et al., 2020). The difference in findings may be due to parents’ higher level of education and income in their sample areas compared with Chinese rural parents, which may have a positive impact on the dietary diversity of children and adolescents.

There are some factors that may explain the impact of the pandemic on the consumption of protein-rich foods. First, the incomes of rural students’ parents may be affected by the pandemic, which may limit their purchases of a variety of foods, especially relatively expensive protein-rich foods (Yu et al., 2020; Dou et al., 2021). Second, COVID-19 has transformed people’s eating habits and food choices. For example, people have spontaneously reduced their intake of raw and frozen food (Zhang et al., 2020), as many countries found the virus on packages of frozen food (Fisher et al., 2020; Liu et al., 2020b).

Table 7. Fixed-effect estimates for the effect of COVID-19 on rural students’ dietary diversity outcomes

| Variable (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) | (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) |
|-----------------------------------------------|-----------------------------------------------|
| DDS Grains Tubers Vegetables Fruit Meats Eggs Aquatic Soybean Milk and milk products products products products products products products products products products |
| Year × Rural −0.295*** (0.109) −0.003 (0.007) 0.018 (0.018) −0.018** (0.007) −0.024 (0.024) −0.040 (0.017) −0.053 (0.021) −0.067 (0.034) −0.060*** (0.020) −0.014 (0.020) |
| Rural 0.169** (0.079) 0.001 (0.006) 0.021 (0.014) 0.012** (0.005) 0.005 (0.015) 0.035*** (0.013) 0.027 (0.021) 0.039* (0.021) 0.037** (0.015) 0.008 (0.014) |
| Year 0.042 (0.149) −0.007* (0.004) −0.004 (0.020) 0.007 (0.008) 0.007 (0.015) 0.002 (0.020) 0.006 (0.026) −0.012 (0.043) 0.008 (0.024) 0.033* (0.020) |
| Control variable YES YES YES YES YES YES YES YES YES YES |
| Observations 7,084 7,084 7,084 7,084 7,084 7,084 7,084 7,084 7,084 7,084 |

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. “Year” is a dummy variable, with 1 representing “after the pandemic” (2020) and 0 representing “before the pandemic” (2019). Standard errors are in parentheses, adjusted for clustering at the school level.

3. Mechanisms for income affecting dietary diversity

We found that the DDS significantly decreased by 0.429 points \((p < 0.05)\) for students from rural families in the high household income group compared with urban students from the high household income group, after controlling for students’ personal and household characteristics. Specifically, the pandemic reduced the consumption of tubers, vegetables, and protein-rich foods (meats, eggs, and soybean products or nuts) among rural students from the high household income group. Compared with urban parents, rural parents are more likely to have unstable jobs (waiters, deliverymen, etc.) or small businesses (selling vegetables, food stalls, etc.); hence, their jobs and incomes are generally unstable. The incomes of high-income households in the rural sample are more

©2021 Institute of World Economics and Politics, Chinese Academy of Social Sciences
likely to be affected by COVID-19 than those of high-income households in the urban sample; hence, dietary diversity is negatively affected by income instability. There was no significant difference between rural and urban families in middle- or low-income families. We also conducted an analysis based on the income-grouping method within the same hukou registration type in 2019. The results based on this income-grouping method were not significantly different from the results presented in Table 8 and Appendix B.

We can see from Appendix B that the DDS significantly decreased by 0.479 points ($p < 0.01$) for students from rural families in the high household income group compared with urban students from the high household income group, after controlling for students’ personal and household characteristics. Specifically, the pandemic significantly reduced the consumption of tubers, vegetables, and protein-rich foods (meats, eggs, soybean products and nuts, milk, and milk products) among rural students from the high household income group.

For boarding students, it is possible that most of their food at school is not their own choice; hence, the DDS of students could be related to a school fixed effect. We have excluded the boarding students from our analysis and the result is similar to the result for the whole sample (Appendix C).

Table 8. Heterogeneous effects of COVID-19 on the dietary diversity of different household income groups

| Outcomes             | All         | Subgroup               |
|----------------------|-------------|------------------------|
|                      | Low-income group | Middle-income group | High-income group |
| Dietary diversity scores | $-0.295^{***}$ | $-0.233$ | $-0.037$ | $-0.429^{**}$ |
|                      | (0.109)     | (0.160)               | (0.147)     | (0.187)         |
| Grains               | $-0.003$    | $-0.005$              | 0.004      | $-0.003$       |
|                      | (0.007)     | (0.012)               | (0.008)    | (0.018)         |
| Tubers               | $-0.018$    | 0.030                  | $-0.011$   | $-0.071^{*}$   |
|                      | (0.018)     | (0.030)               | (0.030)    | (0.037)         |
| Vegetables           | $-0.018^{**}$ | $-0.041^{***}$        | 0.011      | $-0.024^{*}$   |
|                      | (0.007)     | (0.013)               | (0.013)    | (0.012)         |
| Fruit                | $-0.024$    | $-0.026$              | $-0.017$   | $-0.011$       |
|                      | (0.024)     | (0.037)               | (0.024)    | (0.023)         |
| Meats                | $-0.040^{**}$ | $-0.017$              | $-0.023$   | $-0.056^{*}$   |
|                      | (0.017)     | (0.023)               | (0.030)    | (0.033)         |
| Eggs                 | $-0.053^{**}$ | $-0.038$              | $-0.007$   | $-0.089^{***}$ |
|                      | (0.021)     | (0.033)               | (0.034)    | (0.032)         |
| Aquatic products     | $-0.067^{*}$ | $-0.072$              | $-0.005$   | $-0.070$       |
|                      | (0.034)     | (0.046)               | (0.045)    | (0.060)         |
| Soybean products and nuts | $-0.060^{***}$ | $-0.057$          | $-0.012$   | $-0.063^{*}$   |
|                      | (0.020)     | (0.038)               | (0.026)    | (0.036)         |
| Milk and milk products | $-0.014$    | $-0.008$              | 0.023      | $-0.043$       |
|                      | (0.020)     | (0.037)               | (0.031)    | (0.034)         |
| Observations         | 7,084       | 2,334                 | 2,434      | 2,316           |

Notes: ***; **; and * represent significance at the 1, 5, and 10 percent levels, respectively. All the coefficients in this table are “year × rural” coefficients, estimated using a fixed effects model, controlling for the characteristics of students, parents, and families. Standard errors are in parentheses, adjusted for clustering at the school level.
4. Heterogeneous analysis

The pandemic may have had different effects on the dietary diversity of children and adolescents owing to gender and age. There were gender differences in dietary preferences and nutritional status of school-age children (Cooke and Wardle, 2005). As they grow, school-age children gradually form their dietary behaviors and adolescents form regular eating behaviors (Scaglioni et al., 2018). The pandemic may therefore have had different degrees of impact on students of different ages and genders. We therefore present a heterogeneous analysis of the effect of COVID-19 on the dietary diversity of rural students of different ages (primary school or junior high school) and gender (male or female) compared with urban students.

As Table 9 shows, we found that male rural students’ DDS significantly decreased by 0.390 points \( (p < 0.01) \) compared with urban male students. Specifically, the pandemic reduced the variety of tubers, vegetables, and protein-rich foods (meats, eggs, aquatic products, soybean products, and nuts) among rural male students. Junior high-school students from rural families also had significantly worse DDSs \(-0.421, \ p < 0.01\). This may be because the household income of rural male students is more affected by

| Table 9. Heterogeneous effects of COVID-19 on the dietary diversity of different age and gender groups |
|---------------------------------------------------------------|
| **Outcomes** | **All** | **Subgroup** | **Male** | **Female** | **Primary school** | **Junior high school** |
|----------------|----------|--------------|----------|-----------|-------------------|----------------------|
| Dietary diversity scores | \(-0.295***\) | \(-0.390***\) | \(-0.203\) | \(-0.178\) | \(-0.421***\) | \(0.109\) | \(0.120\) | \(0.150\) | \(0.161\) | \(0.118\) |
| Grains | \(-0.003\) | \(-0.010\) | \(0.004\) | \(-0.000\) | \(-0.006\) | \(0.007\) | \(0.010\) | \(0.011\) | \(0.011\) | \(0.008\) |
| Tubers | \(-0.018\) | \(-0.042*\) | \(0.004\) | \(-0.006\) | \(-0.031\) | \(0.018\) | \(0.022\) | \(0.027\) | \(0.026\) | \(0.020\) |
| Vegetables | \(-0.018**\) | \(-0.017*\) | \(-0.017**\) | \(-0.018*\) | \(-0.015**\) | \(0.007\) | \(0.010\) | \(0.009\) | \(0.011\) | \(0.007\) |
| Fruit | \(-0.024\) | \(-0.028\) | \(-0.020\) | \(-0.009\) | \(-0.043\) | \(0.024\) | \(0.028\) | \(0.029\) | \(0.021\) | \(0.053\) |
| Meats | \(-0.040**\) | \(-0.045*\) | \(-0.036\) | \(-0.052**\) | \(-0.013\) | \(0.017\) | \(0.024\) | \(0.024\) | \(0.022\) | \(0.024\) |
| Eggs | \(-0.053**\) | \(-0.057**\) | \(-0.050\) | \(-0.042\) | \(-0.060**\) | \(0.021\) | \(0.027\) | \(0.032\) | \(0.027\) | \(0.030\) |
| Aquatic products | \(-0.067*\) | \(-0.085**\) | \(-0.050\) | \(-0.012\) | \(-0.143***\) | \(0.034\) | \(0.039\) | \(0.041\) | \(0.049\) | \(0.034\) |
| Soybean products and nuts | \(-0.060***\) | \(-0.087***\) | \(-0.033\) | \(-0.042\) | \(-0.080***\) | \(0.020\) | \(0.024\) | \(0.027\) | \(0.027\) | \(0.030\) |
| Milk and milk products | \(-0.014\) | \(-0.023\) | \(-0.006\) | \(0.001\) | \(-0.033\) | \(0.020\) | \(0.029\) | \(0.027\) | \(0.029\) | \(0.029\) |
| Observations | 7084 | 3369 | 3715 | 4402 | 2682 |

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. All the coefficients in this table are “year × rural” coefficients, estimated using a fixed effects model, controlling for the characteristics of students, parents, and families. Standard errors are in parentheses, adjusted for clustering at the school level.
COVID-19 than that of urban male students. The decrease in income leads to lower consumption of protein-rich foods and less dietary diversity. In the junior high-school stage of schooling, students will gradually form their own dietary preferences and choose more foods they like. Compared with urban junior high-school students, rural junior high-school students’ DDS is lower, which may be because rural junior high-school parents are too busy with work to intervene in their children’s diet or they do not care much about the diversity dietary of children. By contrast, parents of urban junior high-school students were more concerned about their children’s dietary diversity, and intervened more in their children’s diets.

IV. Conclusions

In this research, we studied the impact of COVID-19 on the dietary diversity of urban and rural children and adolescents in northern China. Using panel data from a sample of students, collected in two waves (before and after the pandemic outbreak), we found that COVID-19 had a negative impact on dietary diversity. We also found that COVID-19 had a larger effect on dietary diversity among male rural school-aged students and junior high-school students compared with the effect on other students.

We believe that these findings regarding dietary diversity are related to food availability and lifestyle changes, and especially to a reduction in household income. For example, policies controlling the spread of the pandemic have made it more difficult to obtain fresh and frozen foods. People have reduced their activity and have changed their eating habits. The pandemic has also caused fluctuations in rural migrant workers’ incomes, limiting their purchase of various foods, especially relatively expensive protein-rich foods.

Our results have several important implications for policymakers in China. To ensure children’s and adolescents’ dietary diversity, the government should pay more attention to food supplies and provide abundant and affordable food to low household income families and rural families. The government should encourage school-aged students to have a balanced and diverse diet, especially male and junior high-school students. Finally, government policy should consider both food supply and school-aged students’ eating habits to ensure food diversity of children and adolescents under the influence of COVID-19.

References

Bi, J., C. Liu, S. Li, Z. He, K. Chen et al., 2019, “Dietary diversity among preschoolers: A cross-
sectional study in poor, rural, and ethnic minority areas of central South China,” *Nutrients*, Vol. 11, No. 3, p. 558.

Bong, C., C. Brasher, E. Chikumba, R. Mcdougall, J. Mellin-Olsen and A. Enright, 2020, “The COVID-19 pandemic: Effects on low- and middle-income countries,” *Anesthesia and Analgesia*, Vol. 131, No. 1, pp. 86–92.

Calder, P. C., A. C. Carr, A. F. Gombart and M. Eggersdorfer, 2020, “Optimal nutritional status for a well-functioning immune system is an important factor to protect against viral infections,” *Nutrients*, Vol. 12, No. 4, p. 1181.

Carroll, N., A. Sadowski, A. Laila, V. Hruska, M. Nixon et al., 2020, “The impact of COVID-19 on health behavior, stress, financial and food security among middle to high income Canadian families with young children,” *Nutrients*, Vol. 12, No. 8, p. 2352.

Casey, P. H., K. Szeto, S. Lensing, M. Bogle and J. Weber, 2001, “Children in food-insufficient, low-income families: Prevalence, health, and nutrition status,” *Archives of Pediatrics and Adolescent Medicine*, Vol. 155, No. 4, pp. 508–14.

Cecchetto, C., M. Aiello, C. Gentili, S. Ionta and S. A. Osimo, 2021, “Increased emotional eating during COVID-19 associated with lockdown, psychological and social distress,” *Appetite*, Vol. 160, No. 105122, pp. 1–9.

Chen, S., J. Yang, W. Yang, C. Wang and T. Bärnighausen, 2020, “COVID-19 control in China during mass population movements at New Year,” *The Lancet*, Vol. 395, No. 10226, pp. 764–66.

Cheval, B., H. Sivaramakrishnan, S. Maltagliati, L. Fessler, C. Forestier et al., 2021, “Relationships between changes in self-reported physical activity, sedentary behaviour and health during the coronavirus (COVID-19) pandemic in France and Switzerland,” *Journal of Sports Sciences*, Vol. 39, No. 6, pp. 699–704.

Cooke, L. J. and J. Wardle, 2005, “Age and gender differences in children’s food preferences,” *British Journal of Nutrition*, Vol. 93, No. 5, pp. 741–6.

Dou, Z., D. Stefanovski, D. Galligan, M. Lindem, P. Rozin et al., 2021, “Household food dynamics and food system resilience amid the COVID-19 pandemic: A cross-national comparison of China and the United States,” *Frontiers in Sustainable Food Systems*, Vol. 4, No. 577153, pp. 1–11.

Fang, Y., Y. Nie and M. Penny, 2020, “Transmission dynamics of the COVID-19 outbreak and effectiveness of government interventions: A data-driven analysis,” *Journal of Medical Virology*, Vol. 92, No. 6, pp. 645–59.

Fisher, D., A. Reilly, A. K. E. Zheng, A. R. Cook and D. Anderson, 2020, “Seeding of outbreaks of COVID-19 by contaminated fresh and frozen food” [online; cited September 2021]. Available from: https://www.researchgate.net/publication/343741192_Seeding_of_outbreaks_of_COVID-19_by_contaminated_fresh_and_frozen_food.

Fore, H. H., D. Qu, D. M. Beasley and T. A. Ghebreyesus, 2020, “Child malnutrition and COVID-19: The time to act is now,” *The Lancet*, Vol. 396, No. 10250, pp. 517–8.
Fulkerson, J. A., S. Friend, M. Horning, C. Flattum, M. Draxten et al., 2018, “Family home food environment and nutrition-related parent and child personal and behavioral outcomes of the Healthy Home Offerings via the Mealtime Environment (HOME) Plus program: A randomized controlled trial,” *Journal of the Academy of Nutrition and Dietetics*, Vol. 118, No. 2, pp. 240–51.

Golberstein, E., H. Wen and B. F. Miller, 2020, “Coronavirus disease 2019 (COVID-19) and mental health for children and adolescents,” *JAMA Pediatrics*, Vol. 174, No. 9, pp. 819–20.

Harris, J., L. Depenbusch, A. A. Pal, R. M. Nair and S. Ramasamy, 2020, “Food system disruption: Initial livelihood and dietary effects of COVID-19 on vegetable producers in India,” *Food Security*, Vol. 12, No. 4, pp. 841–51.

Headey, D., R. Heidkamp, S. Osendarp, M. Ruel, N. Scott et al., 2020, “Impacts of COVID-19 on childhood malnutrition and nutrition-related mortality,” *The Lancet*, Vol. 396, No. 10250, pp. 519–21.

Ho, C., C. Chee and R. Ho, 2020, “Mental health strategies to combat the psychological impact of COVID-19 beyond paranoia and panic,” *Ann Acad Med Singapore*, Vol. 49, No. 1, pp. 1–3.

Ji, D., Y. Ji, X. Duan, W. Li, Z. Sun et al., 2017, “Prevalence of psychological symptoms among Ebola survivors and healthcare workers during the 2014–2015 Ebola outbreak in Sierra Leone: A cross-sectional study,” *Oncotarget*, Vol. 8, No. 8, pp. 12784–91.

Kansiime, M. K., J. A. Tambo, I. Mugambi, M. Bundi, A. Kara and C. Owuor, 2021, “COVID-19 implications on household income and food security in Kenya and Uganda: Findings from a rapid assessment,” *World Development*, Vol. 137, p. 105199.

Kennedy, G., T. Ballard and M. C. Dop, 2013, “Guidelines for measuring household and individual dietary diversity” [online; cited October 2021]. Available from: https://www.fao.org/3/i1983e/I1983E.pdf.

Kennedy, G. L., M. R. Pedro, C. Seghieri, G. Nantel and I. Brouwer, 2007, “Dietary diversity score is a useful indicator of micronutrient intake in non-breast-feeding Filipino children,” *Journal of Nutrition*, Vol. 137, No. 2, pp. 472–7.

Köhler-Forsberg, O., L. Petersen, C. Gasse, P. B. Mortensen, S. Dalsgaard et al., 2019, “A nationwide study in Denmark of the association between treated infections and the subsequent risk of treated mental disorders in children and adolescents,” *JAMA Psychiatry*, Vol. 76, No. 3, pp. 271–9.

Kong, X., F. Liu, H. Wang, R. Yang, D. Chen et al., 2020, “Epidemic prevention and control measures in China significantly curbed the epidemic of COVID-19 and influenza,” *Journal of Virus Eradication*, Vol. 7, No. 2, p. 100040.

Leddy, A. M., S. D. Weiser, K. Palar and H. Seligman, 2020, “A conceptual model for understanding the rapid COVID-19–related increase in food insecurity and its impact on health and healthcare,” *The American Journal of Clinical Nutrition*, Vol. 112, No. 5, pp. 1162–9.
Lee, T., I. Chi, L. Chung and K. Chou, 2006, “Ageing and psychological response during the post-SARS period,” Aging and Mental Health, Vol. 10, No. 3, pp. 303–11.
Liu, J., Y. Bao, X. Huang, J. Shi and L. Lu, 2020a, “Mental health considerations for children quarantined because of COVID-19,” The Lancet Child and Adolescent Health, Vol. 4, No. 5, pp. 347–9.
Liu, P., M. Yang, X. Zhao, Y. Guo, L. Wang et al., 2020b, “Cold-chain transportation in the frozen food industry may have caused a recurrence of COVID-19 cases in destination: Successful isolation of SARS-CoV-2 virus from the imported frozen cod package surface,” Biosafety and Health, Vol. 2, No. 4, pp. 199–201.
Mason, T. B., J. Barrington-Trimis and A. M. Leventhal, 2021, “Eating to cope with the COVID-19 pandemic and body weight change in young adults,” Journal of Adolescent Health, Vol. 68, No. 2, pp. 277–83.
Mussell, A., T. Bilyea and D. Hedley, 2020, “Agri-food supply chains and Covid-19: Balancing resilience and vulnerability,” Agri-Food Economic Systems, pp. 1–6.
Qiu, H., J. Wu, L. Hong, Y. Luo, Q. Song et al., 2020, “Clinical and epidemiological features of 36 children with coronavirus disease 2019 (COVID-19) in Zhejiang, China: An observational cohort study,” The Lancet Infectious Diseases, Vol. 20, No. 6, pp. 689–96.
Ruiz-Roso, M. B., P. De C. Padilha, D. C. Mantilla-Escalante, N. Ulloa, P. Brun et al., 2020, “Covid-19 confinement and changes of adolescent’s dietary trends in Italy, Spain, Chile, Colombia and Brazil,” Nutrients, Vol. 12, No. 6, p. 1807.
Scaglioni, S., V. De Cosmi, V. Ciappolino, F. Parazzini, P. Brambilla et al., 2018, “Factors influencing children’s eating behaviours,” Nutrients, Vol. 10, No. 6, p. 706.
Simmons, D. and G. E. Chapman, 2012, “The significance of home cooking within families,” British Food Journal, Vol. 114, No. 8, pp. 1184–95.
Steyn, N. P., J. H. Nel, G. Nantel, G. Kennedy and D. Labadarios, 2006, “Food variety and dietary diversity scores in children: Are they good indicators of dietary adequacy?” Public Health Nutrition, Vol. 9, No. 5, pp. 644–50.
WHO, 2021, “Weekly epidemiological update on COVID-19–5 October 2021” [online; cited October 2021]. Available from: https://www.who.int/publications/m/item/weekly-epidemiological-update-on-covid-19---5-october-2021.
Yu, X., C. Liu, H. Wang and J. Feil, 2020, “The impact of COVID-19 on food prices in China: Evidence of four major food products from Beijing, Shandong and Hubei Provinces,” China Agricultural Economic Review, Vol. 12, No. 3, pp. 445–58.
Zhang, J., A. Zhao, Y. Ke, S. Huo, Y. Ma et al., 2020, “Dietary behaviors in the post-lockdown period and its effects on dietary diversity: The second stage of a nutrition survey in a longitudinal Chinese study in the COVID-19 era,” Nutrients, Vol. 12, No. 11, p. 3269.
Zhao, A., Z. Li, Y. Ke, S. Huo, Y. Ma et al., 2020, “Dietary diversity among Chinese residents during the COVID-19 outbreak and its associated factors,” Nutrients, Vol. 12, No. 6, p. 1699.
Appendix A: Comparison of dietary diversity variables in 2019 and 2020 between different income groups

| Variable                      | Low-income group | Middle-income group | High-income group |
|-------------------------------|------------------|---------------------|-------------------|
|                               | 2019     | 2020          | MeanDiff | 2019     | 2020          | MeanDiff | 2019     | 2020          | MeanDiff |
| Dietary diversity scores      | 7.45     | 7.15          | −0.30*** | 7.40     | 7.32          | −0.08    | 7.41     | 7.50          | 0.09     |
| Grains                        | 0.98     | 0.97          | −0.01    | 0.99     | 0.97          | −0.02**  | 0.98     | 0.98          | 0.00     |
| Tubers                        | 0.86     | 0.86          | 0.00     | 0.82     | 0.82          | 0.00     | 0.83     | 0.84          | 0.01     |
| Vegetables                    | 0.98     | 0.97          | −0.01    | 0.97     | 0.97          | 0.00     | 0.97     | 0.98          | 0.01     |
| Fruit                         | 0.88     | 0.87          | −0.01    | 0.90     | 0.89          | −0.01    | 0.90     | 0.92          | 0.02     |
| Meats                         | 0.90     | 0.86          | −0.04*** | 0.88     | 0.89          | 0.01     | 0.88     | 0.90          | 0.02     |
| Eggs                          | 0.76     | 0.72          | −0.04**  | 0.75     | 0.76          | 0.01     | 0.76     | 0.78          | 0.02     |
| Aquatic products              | 0.47     | 0.35          | −0.12*** | 0.47     | 0.41          | −0.06*** | 0.48     | 0.45          | −0.03    |
| Soybean products and nuts     | 0.84     | 0.76          | −0.08*** | 0.81     | 0.80          | −0.01    | 0.81     | 0.82          | 0.01     |
| Milk and milk products        | 0.79     | 0.80          | 0.01     | 0.81     | 0.82          | 0.01     | 0.82     | 0.84          | 0.02*    |

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. Low-, middle- and high-income groups were defined separately for rural and urban areas following the three-equal-group rule within rural or urban samples. The low-, middle- and high-income groups in this table refer to the combined rural and urban low-, middle- and high-income groups.

Appendix B: Heterogeneous effects of COVID-19 on the dietary diversity of different household income groups

| Outcomes                      | All              | Subgroup         |
|-------------------------------|------------------|------------------|
|                               | Low-income group | Middle-income group | High-income group |
| Dietary diversity scores      | −0.295*** (0.109) | −0.252 (0.173) | −0.121 (0.149) | −0.476*** (0.182) |
| Grains                        | −0.003 (0.007)   | −0.007 (0.013)   | −0.003 (0.011) | −0.000 (0.014)   |
| Tubers                        | −0.018 (0.018)   | 0.035 (0.030)    | −0.019 (0.036) | −0.062* (0.032)  |
| Vegetables                    | −0.018** (0.007) | −0.031*** (0.012)| −0.011 (0.013) | −0.013 (0.013)   |
| Fruit                         | −0.024 (0.024)   | −0.037 (0.036)   | 0.002 (0.027)  | −0.036 (0.032)   |
| Meats                         | −0.040** (0.017) | −0.010 (0.026)   | −0.053* (0.030)| −0.051* (0.029)  |
| Eggs                          | −0.053** (0.021) | −0.050 (0.032)   | 0.009 (0.032)  | −0.110*** (0.031)|
| Aquatic products              | −0.067* (0.034)  | −0.080 (0.051)   | −0.027 (0.042) | −0.083 (0.059)   |
| Soybean products and nuts     | −0.060*** (0.020)| −0.054 (0.042)   | −0.049* (0.027)| −0.069** (0.034) |
| Milk and milk products        | −0.014 (0.020)   | −0.018 (0.035)   | 0.030 (0.039)  | −0.051* (0.030)  |
| Observations                  | 7084             | 2256             | 2324           | 2504             |

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. All the coefficients in this table are “year × rural” coefficients estimated using a fixed effects model, controlling for the characteristics of students, parents, and families. Standard errors are indicated in parentheses, adjusted for clustering at the school level. Low-, middle- and high-income groups were defined separately for rural and urban area following the three-equal-group rule within rural or urban samples. The low-, middle- and high-income groups in this table refer to the combined rural and urban low-, middle- and high-income groups.
Appendix C: Heterogeneous effects of COVID-19 on the dietary diversity of different household income groups (excluding boarding students)

| Outcomes                      | All          | Subgroup               |
|-------------------------------|--------------|------------------------|
|                               | Low-income group | Medium-income group | High-income group |
| Dietary diversity scores      | −0.189**     | −0.163                 | 0.083             | −0.324**       |
|                               | −0.09        | (0.168)                | (0.152)           | (0.156)        |
| Grains                        | −0.002       | −0.004                 | 0.004             | −0.005         |
|                               | −0.009       | (0.018)                | (0.014)           | (0.016)        |
| Tubers                        | −0.019       | 0.022                  | 0.004             | −0.074**       |
|                               | −0.021       | (0.036)                | (0.037)           | (0.038)        |
| Vegetables                    | −0.016*      | −0.045***              | 0.009             | −0.011         |
|                               | −0.009       | (0.017)                | (0.017)           | (0.016)        |
| Fruit                         | −0.007       | −0.010                 | −0.006            | 0.008          |
|                               | −0.014       | (0.026)                | (0.024)           | (0.025)        |
| Meats                         | −0.039**     | −0.009                 | −0.022            | −0.068**       |
|                               | −0.018       | (0.033)                | (0.032)           | (0.033)        |
| Eggs                          | −0.039*      | −0.031                 | 0.016             | −0.074*        |
|                               | −0.022       | (0.041)                | (0.037)           | (0.041)        |
| Aquatic products              | −0.035       | −0.069                 | 0.031             | −0.035         |
|                               | −0.026       | (0.047)                | (0.046)           | (0.045)        |
| Soybean products and nuts     | −0.036*      | −0.037                 | 0.024             | −0.055         |
|                               | −0.02        | (0.037)                | (0.034)           | (0.035)        |
| Milk and milk products        | 0.006        | 0.022                  | 0.026             | −0.008         |
|                               | −0.018       | (0.035)                | (0.030)           | (0.032)        |
| Observations                  | 5101         | 1607                   | 1720              | 1774           |

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. All the coefficients in this table are “year × rural” coefficients estimated by controlling the school fixed-effect and characteristics of students, parents, and families. Standard errors are in parentheses, adjusted for clustering at the school level.

(Edited by Jin Song)

Corrigendum

In the article by Rogoff and Yang, Figure 24 has been published with incorrect title. The correct title is: Figure 24. Impact of real estate related activities’ on GDP by country, 1997–2017.

Reference
Rogoff, K. and Y. Yang, 2021, “Has China’s Housing Production Peaked?” China & World Economy, Vol. 29, No. 1, pp. 1–31. https://doi.org/10.1111/cwe.12360

©2021 Institute of World Economics and Politics, Chinese Academy of Social Sciences