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Impacts of COVID-19 on Nutritional Intake in Rural China: Panel Data Evidence

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Abstract: The COVID-19 pandemic introduced risks and challenges to global food and nutrition security. In this paper, we examine the impact of the COVID-19 pandemic on the nutritional intake of China's rural residents using panel data and a fixed effect model. The data were collected in 2019 and 2020 and covered nine provinces and 2,631 households in rural China. The results reveal that an increase of 100 confirmed cases in a county resulted in a 1.48% ($p<0.01$), 1.46% ($p<0.01$), 1.77% ($p<0.01$), and 1.23% ($p<0.01$) decrease in per capita intake of dietary energy, carbohydrates, fats, and proteins, respectively. Moreover, the COVID-19 pandemic only had a significant and negative effect on dietary energy intake in the low-income group at the 5% level of significance. Our study indicates that the potential insufficient nutrition situation, nutritional imbalance, and dietary imbalance of low-income rural residents should be addressed appropriately.

Keywords: COVID-19; nutritional intake; rural China; food consumption; food security

1. Introduction

The COVID-19 pandemic has been ongoing since January 2020 as a result of its rapid and widespread transmission and its difficulty in prevention and control [1-3]. As of 13 May 2022, there were 517,648,631 confirmed cases, including 6,261,708 deaths worldwide [4]. The epidemic has had a profound impact on the global economy and welfare, such as business shutdowns, job losses, disrupted supply chains, commodity price volatility, etc. [5-8]. Moreover, the pandemic introduced risks and challenges to global food and nutrition security [9,10] and made the pathway towards SDG2 even steeper [11], especially in rural areas of the developing world [12-15]. The channels through which the pandemic affects food and nutrition security comprise all four pillars of food security. Food availability and stability are affected by a lack of workers [16], delays in agricultural work [17], an increase in the price of food and materials [18-21], and trade restrictions [22]. Moreover, major threats to food access and utilization posed by COVID-19 are the loss of household income, reduced purchasing power [23-25], and supply chain disruptions caused by lockdown measures [26-28].

In this paper, we examine the impact of the COVID-19 pandemic on nutritional intake, a key aspect of food utilization and SDG2 [29]. Recent literature shows that the pandemic has had a significant but heterogeneous impact on nutritional intake. The consumption of nutrient-dense foods, such as vegetables, fruit, and animal-source food, has been reduced, while the consumption of carbohydrate-containing foods, such as bread, increases [30-32]. However, the lockdown policy led to an increase in fruit, vegetables, and fat consumption in some developed countries [33]. In terms of specific populations, the pandemic impact on Dutch older adults was negative [34], while the impact on Australian university students was positive [35]. Furthermore, evidence shows that the COVID-19

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pandemic might affect the dietary structure and consumer behavior [36,37]. For example, consumers may prefer healthy diets [38,39], the demand for online food delivery may increase [40,41], panic buying may occur [42], and sustainable food consumption may be promoted [43-45].

The COVID-19 pandemic seriously affected rural China [32]. About 27% of the agri-food system's workers (about 46 million) lost their jobs due to COVID-19 during the lockdown phase (January 2020 - March 2020) [46]. According to a survey in mid-February 2020, 23% of households who have been out of poverty since 2013 believed they might return to poverty [47]. However, only a few studies have evaluated the impacts of the COVID-19 pandemic on the dietary diversity [48,49] and food consumption of China's rural residents [50]. Tian et al. (2022) found that COVID-19 positively affected rural households' consumption of vegetables, aquaculture, and legumes, but COVID-19 significantly reduced rural households' dietary diversity [50]. To the best of our knowledge, the pandemic impact on the nutritional intake of China's rural residents is still unknown.

Three contributions are made in this article to the existing literature. First, we try to fill the research gap by investigating the COVID-19 pandemic impact on the nutritional intake of China's rural residents. Second, we identify the heterogeneity of the pandemic impact among different income groups in addition to considering the different impacts of the pandemic on countries with different income levels. Third, since most similar studies use cross-sectional data [34,35] or non-national and small size panel data [50], we use a nationwide panel data with nine provinces and 2,631 rural households and a fixed effect model following Amare et al. (2021) [23] to control for the unobserved factors, such as dietary preferences.

2. Materials and Methods

2.1. Study Design

We empirically evaluated the impact of the COVID-19 pandemic on Chinese rural residents' nutritional intake using a multiple fixed effect (FE) model. The baseline regression is as follows:

$$\ln Nutrition_{hcpt} = \beta_0 + \beta_1 COVID_{ct} + \beta X_{hcpt} + \alpha_h + \varepsilon_{hcpt} \quad (1)$$

where the outcome variable $Nutrition_{hcpt}$ indicates the quantity of the nutritional intake of household h in county c, province p, and time t. In this paper, the outcome variable includes dietary energy, carbohydrate, fat, and protein. $COVID_{ct}$ is the key explanatory variable, indicating the number of confirmed COVID-19 cases. X_{hcpt} is a matrix of control variables, including the price of nutrients, expenditure, and family size. α_h is the household fixed effect, and ε_{hcpt} is the error term. β_1 is the key parameter indicating the impact of COVID-19 on nutritional intake, indicating one more confirmed case in a county would result in a $100\times\beta_1$% change in nutrient intake in *ceteris paribus* condition.

To control for the unobservable aspects that stay constant within the county, province, and time, we add three more parameters to Eq. (1).

$$\ln Nutrition_{hcpt} = \beta_0 + \beta_1 COVID_{ct} + \beta X_{hcpt} + \alpha_h + \delta_c + \theta_p + \gamma_t + \varepsilon_{hcpt} \quad (2)$$

where δ_c is county fixed effect, which controls all time-invariant county-level characteristics. Moreover, θ_p and γ_t indicate the province and time fixed effect, respectively.

2.2. Data Collection

We used the 2019-2020 Survey for Agriculture and Village Economy (SAVE) data collected by the Institute of Agricultural Economics and Development, Chinese Academy of Agricultural Sciences [51,52]. The 2019-2020 SAVE data record the annual production, consumption, expenditure, and income of the rural households and cover 5,818 observations in the Hebei, Jilin, Heilongjiang, Anhui, Fujian, Henan, Hunan, Sichuan, and Yunnan provinces of China (Figure 1). Moreover, the number of accumulated confirmed COVID-19 cases in each county by the end of December 2020 was collected by Wind Info. We also

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used the consumer price index (CPI) data from the National Bureau of Statistics of China (NBSC).

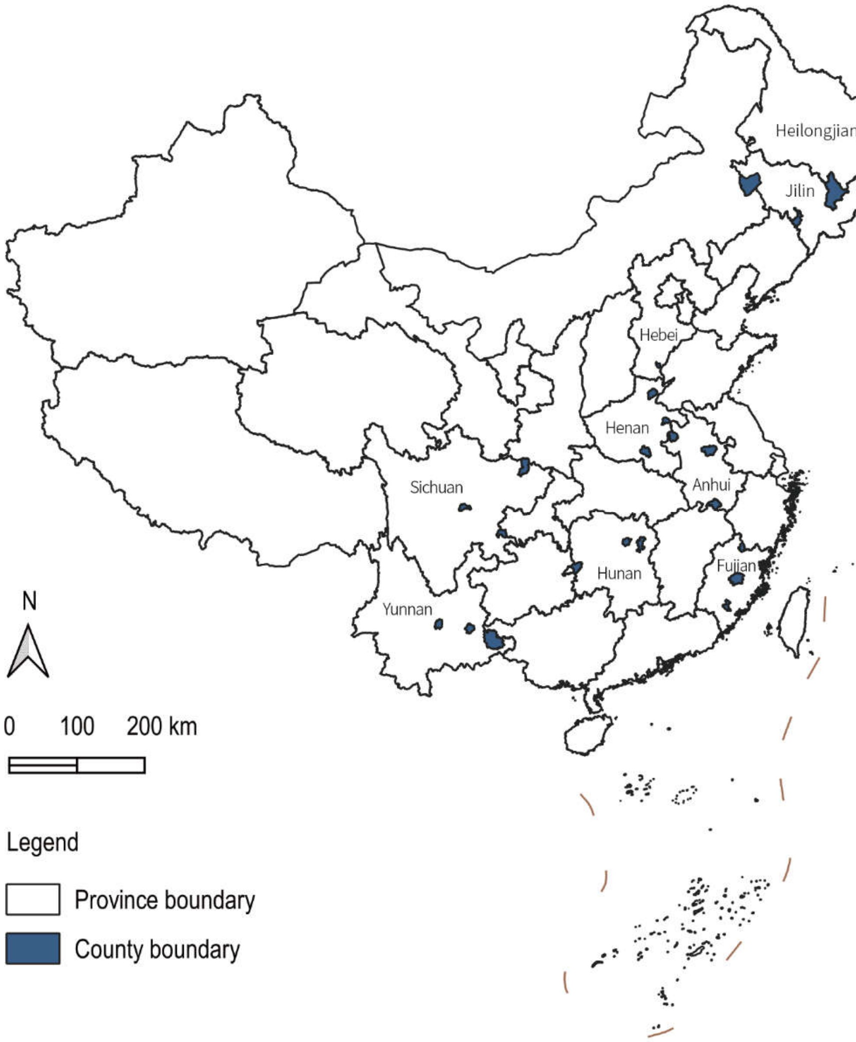

Figure 1. The geographical location of the study areas.

2.3. Outcome Variables

Since the SAVE data only contains at-home consumption information of households for 18 food items, we first divided the household food consumption by the family size to obtain the per capita food consumption (kg/year), then converted the per capita food consumption into per capita intake of dietary energy (kcal/day), carbohydrates (g/day), fat (g/day), and protein (g/day), based on the China Food Composition [53].

However, this method may have underestimated the nutritional intake because it ignores other food (not included in the 18 categories) consumed at home and all food consumed away from home. We assumed that the nutritional content of other food consumed at home and all food consumed away from home was proportional to the 18 categories of food consumed at home as a function of expenditure [54]. Meanwhile, we assumed 50% of food expenditures away from home pertained to food quantities consumed [55]. Thus, the proportion of the 18 categories of food expenditure in the total food expenditure can be expressed as follows:

$$\omega = \sum_i x_i \Big/ \left(\sum_i x_i + X_{OT} + 0.5X_{FAFH}\right) \quad (3)$$

where *i*=1,...,18; x_i represents the expenditure on food item *i*; X_{OT} indicates the expenditure on other food (not included in the 18 categories) consumed at home; X_{FAFH} indicates the food expenditure away from home. Thus, the per capita daily intake of nutrient *k* is expressed as:

$$Nutrition_k = \sum_i N_{ik} q_i \gamma_i / \omega \tag{4}$$

where $Nutrition_k$ represents the total intake of nutrient *k* from all food items; N_{ik} is the intake of nutrient *k* obtained from food item *i*; q_i represents the per capita consumption of food item *i*; and γ_i represents the proportion of the edible parts of food item *i*.

2.4. Control Variables

2.4.1. COVID-19

According to the *Law on the Prevention and Control of Infectious Diseases of the People's Republic of China*, the county government can take measures such as stopping work, restricting activities, or lockdown as necessary for public safety. Further, there have been differences in prevention and control policies among counties in China during the COVID-19 pandemic. Thus, we use the cumulative cases at the county level to measure the impact of COVID-19.

2.4.2. Weighted Price of Nutrients

Price is one of the major determinants of consumer behavior [56-58]. As a consequence of the lockdown policies implemented by COVID-19, the food purchase and nutrition intake of rural residents were strongly influenced by price fluctuations [18,59]. However, it was only possible to collect food prices (unit values), not nutrient prices, during the data collection process. Thus, a weighted nutrition price (P_k) is introduced in this paper to describe the price of nutrients.

$$P_k = \sum_{i=1}^{18} \left(\frac{N_{ik}}{Nutrition_k} \times \frac{P_i}{N_{ik}}\right) = \sum_{i=1}^{18} \left(\frac{N_{ik}}{Nutrition_k} \times \frac{E_i/Q_i}{N_{ik}}\right) \tag{5}$$

where P_i is the price of food item *i*; E_i and Q_i indicate the expenditure and consumed quantity of food item *i*, respectively. Further, $\frac{P_i}{N_{ik}}$ indicates the price (or the unit values) of nutrient *k* in food item *i*, and $\frac{N_{ik}}{Nutrition_k}$ indicates the proportion of nutrient *k* obtained from food item *i* in the total intake of nutrient *k* from all food items.

2.4.3. Income, Expenditure, and Family Size

Income, expenditure, and family size are also important determinants of food consumption [56,60-62]. In the single equation model of food consumption, either income or expenditure can be used. In this paper, the per capita annual expenditure was used since respondents usually do not provide their actual incomes. We also used an instrumental estimation of the fixed effect model and use expenditure as the instrumental variable of income.

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Table 1. Definitions of major variables.

Variable	Definition	Unit
COVID	Cumulative cases in the county by the end of 2020	Hundred cases
Carbohydrate	Per capita carbohydrate intake	g/day
Fat	Per capita fat intake	g/day
Protein	Per capita protein intake	g/day
Energy	Per capita dietary energy intake	kcal/day
Price_ch	Weighted price of carbohydrates	CNY/kg
Price_fat	Weighted price of fat	CNY/kg
Price_pt	Weighted price of protein	CNY/kg
Price_energy	Weighted price of dietary energy	CNY/1,000 kcal
Inc	Per capita annual income	1,000 CNY
Exp	Per capita annual expenditure	1,000 CNY
Family_size	Number of family members	/
Year2020	=1 (year=2020); =0 (year=2019)	/

2.5. Data Processing and Cleaning

First, we deleted some samples to construct balanced panel data. Second, we excluded samples with extreme values by winsorizing at the 2% quantile. Third, prices, incomes, and expenditures were deflated by China's annual CPI. After data processing and cleaning, we kept 2,631 rural households, and the total observation was 5,262 (Figure 1).

2.6. Statistical Analysis

As shown in Table 2, the average per capita daily intakes of carbohydrates, fat, protein, and dietary energy in 2019 were 252.88 g, 96.72 g, 48.56 g, and 2,059.43 kcal, respectively. In 2020, average carbohydrate intake increased while fat and protein intake decreased. The per capita daily intake of dietary energy was similar to the *Report on the Nutrition and Chronic Disease Status of Chinese Residents* (2020) [63]. However, the fat intake from the SAVE data was higher than that of the *Report on the Nutrition and Chronic Disease Status of Chinese Residents* (2020), while the carbohydrate and carbohydrate intakes from the SAVE data were lower.

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Table 2. Summary statistics for major variables.

Variable	Pre-COVID-19 (2019)		Post-COVID-19 (2020)		Full Sample	
	Mean	SD	Mean	SD	Mean	SD
COVID	0.00	0.00	0.85	1.23	0.42	0.97
Carbohydrate	252.88	140.21	247.45	137.39	250.17	138.82
Fat	96.72	44.47	98.73	46.13	97.72	45.31
Protein	48.56	22.58	48.73	23.24	48.65	22.91
Dietary_Energy	2059.43	901.08	2057.08	916.28	2058.25	908.62
Price_ch	6.06	10.88	6.47	11.94	6.26	11.42
Price_fat	10.59	7.85	11.07	9.17	10.83	8.54
Price_pt	18.10	7.19	19.08	8.56	18.59	7.91
Price_energy	0.48	0.21	0.51	0.23	0.49	0.22
Inc	17.99	18.76	17.93	19.53	17.96	19.15
Exp	35.86	17.35	36.90	17.92	36.38	17.64
Family_size	3.93	1.60	3.95	1.59	3.94	1.59
Observations	2631		2631		5262	

3. Results

3.1. COVID-19 impact on Dietary Energy Intake

Table 3 sheds light on the impacts of COVID-19 on dietary energy intake. To explore the nonlinear relationship between dietary energy intake and expenditure, we added the square term of the expenditure into equation (2). As shown in Table 3, a negative and significant coefficient of *COVID* indicates that an increase in COVID-19 cases in the counties will significantly reduce the per capita dietary energy intake of rural residents. Specifically, an increase of 100 confirmed cases in a county results in a 1.48% (p<0.01) decrease in per capita dietary energy intake (Column (4) in Table 3).

In addition, our results demonstrate that an increase in weighted energy price led to a decrease in dietary energy intake. The dietary energy intake will decrease by approximately 0.48% (p<0.01) for every 1% increase in price (Column (4) in Table 3). Accordingly, the coefficient on the square term of the expenditure was significantly negative, which indicates that the impact of expenditure on dietary energy intake had an inverted U-shape. Furthermore, the results indicate that a larger family tended to reduce the dietary energy intake of family members, in line with previous research.

Table 3. Estimation results of the COVID-19 impact on dietary energy intake.

Variables	FE model 1 (1)	FE model 2 (2)	FE model 3 (3)	FE model 4 (4)
COVID	-0.0148***	-0.0148***	-0.0148***	-0.0148***
	(0.0035)	(0.0041)	(0.0041)	(0.0041)
ln*Price_energy*	-0.48***	-0.48***	-0.48***	-0.48***
	(0.02)	(0.05)	(0.05)	(0.05)
ln*Exp*	2.40***	2.40***	2.40***	2.40***
	(0.57)	(0.82)	(0.83)	(0.83)
$(\ln Exp)^2$	-0.11***	-0.11***	-0.11***	-0.11***
	(0.03)	(0.04)	(0.04)	(0.04)
Family_size	-0.04***	-0.04***	-0.04***	-0.04***
	(0.01)	(0.02)	(0.02)	(0.02)
Constant term	-9.34***	-9.34**	-9.34**	-9.34**
	(2.97)	(4.25)	(4.26)	(4.26)
Year FE	YES	YES	YES	YES
Household FE	YES	YES	YES	YES
County FE	NO	NO	YES	YES
Province FE	NO	NO	NO	YES
Cluster robust standard errors	None	Village	Village	Village
Observations	5,262	5,262	5,262	5,262

Notes: Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

3.2. COVID-19 impact on Carbohydrate, Fat, and Protein Intakes

From Table 4 to Table 6, the most important highlight is that the increased number of confirmed COVID-19 cases in a county caused a significant reduction in per capita carbohydrate, fat, and protein intake. For every 100 additional cases of COVID-19 in a county, the intake of carbohydrates, fats, and proteins declined by 1.46% (p<0.01), 1.77% (p<0.01), and 1.23% (p<0.01), respectively. Thus, among the three major macronutrients, COVID-19 had the largest relative effect on fat intake in rural China.

In addition, the own-price elasticities of the three macronutrients were negative, and the cross-price elasticities were positive (Table 4 – Table 6). The own-price elasticities of carbohydrate, fat, and protein were -0.87 (p<0.01), -0.76 (p<0.01), and -0.68 (p<0.01), respectively. The result indicates that Chinese rural residents were most sensitive to the price of carbohydrates, and the macronutrients had a significant substitution relationship. An increase in the price of one nutrient will result in the consumer switching to another nutrient to ensure adequate overall calorie intake.

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Table 4. Estimation results of the COVID-19 impact on carbohydrate intake.

Variables	FE model 1 (1)	FE model 2 (2)	FE model 3 (3)	FE model 4 (4)
COVID	-0.0146***	-0.0146***	-0.0146***	-0.0146***
	(0.0036)	(0.0038)	(0.0038)	(0.0038)
lnPrice_ch	-0.87***	-0.87***	-0.87***	-0.87***
	(0.02)	(0.05)	(0.05)	(0.05)
lnPrice_fat	0.33***	0.33***	0.33***	0.33***
	(0.02)	(0.07)	(0.07)	(0.07)
lnPrice_pt	0.16***	0.16*	0.16*	0.16*
	(0.04)	(0.09)	(0.09)	(0.09)
ln*Exp*	2.50***	2.50***	2.50***	2.50***
	(0.60)	(0.92)	(0.92)	(0.92)
$(\ln Exp)^2$	-0.11***	-0.11**	-0.11**	-0.11**
	(0.03)	(0.04)	(0.04)	(0.04)
Family_size	-0.05***	-0.05**	-0.05**	-0.05**
	(0.08)	(0.02)	(0.02)	(0.02)
Constant term	-11.23***	-11.23**	-11.23**	-11.23**
	(3.09)	(4.79)	(4.79)	(4.79)
Year FE	YES	YES	YES	YES
Household FE	YES	YES	YES	YES
County FE	NO	NO	YES	YES
Province FE	NO	NO	NO	YES
Cluster robust standard errors	None	Village	Village	Village
Observations	5,262	5,262	5,262	5,262

Notes: Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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Table 5. Estimation results of the COVID-19 impact on fat intake.

Variables	FE model 1 (1)	FE model 2 (2)	FE model 3 (3)	FE model 4 (4)
COVID	-0.0177***	-0.0177***	-0.0177***	-0.0177***
	(0.0035)	(0.0041)	(0.0041)	(0.0041)
lnPrice_ch	0.09***	0.09*	0.09*	0.09*
	(0.02)	(0.05)	(0.05)	(0.05)
lnPrice_fat	-0.76***	-0.76***	-0.76***	-0.76***
	(0.02)	(0.06)	(0.06)	(0.06)
lnPrice_pt	0.23***	0.23***	0.23***	0.23***
	(0.03)	(0.09)	(0.09)	(0.09)
ln*Exp*	2.39***	2.39***	2.39***	2.39***
	(0.57)	(0.85)	(0.85)	(0.85)
$(\ln Exp)^2$	-0.11***	-0.11**	-0.11**	-0.11**
	(0.03)	(0.04)	(0.04)	(0.04)
Family_size	-0.05***	-0.05**	-0.05**	-0.05**
	(0.01)	(0.02)	(0.02)	(0.02)
Constant term	-10.80***	-10.80**	-10.80**	-10.80**
	(2.95)	(4.40)	(4.40)	(4.40)
Year FE	YES	YES	YES	YES
Household FE	YES	YES	YES	YES
County FE	NO	NO	YES	YES
Province FE	NO	NO	NO	YES
Cluster robust standard errors	None	Village	Village	Village
Observations	5,262	5,262	5,262	5,262

Notes: Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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Table 6. Estimation results of the COVID-19 impact on protein intake.

Variables	FE model 1 (1)	FE model 2 (2)	FE model 3 (3)	FE model 4 (4)
COVID	-0.0123***	-0.0123***	-0.0123***	-0.0123***
	(0.0035)	(0.0039)	(0.0039)	(0.0039)
lnPrice_ch	0.05**	0.05	0.05	0.05
	(0.02)	(0.05)	(0.05)	(0.05)
lnPrice_fat	0.31***	0.31***	0.31***	0.31***
	(0.02)	(0.06)	(0.06)	(0.06)
lnPrice_pt	-0.68***	-0.68***	-0.68***	-0.68***
	(0.03)	(0.08)	(0.08)	(0.08)
ln*Exp*	2.36***	2.36**	2.36**	2.36**
	(0.58)	(0.9)	(0.9)	(0.9)
$(\ln Exp)^2$	-0.11***	-0.11**	-0.11**	-0.11**
	(0.03)	(0.04)	(0.04)	(0.04)
Family_size	-0.04***	-0.04**	-0.04**	-0.04**
	(0.01)	(0.02)	(0.02)	(0.02)
Constant term	-10.16***	-10.16**	-10.16**	-10.16**
	(2.97)	(4.78)	(4.79)	(4.79)
Year FE	YES	YES	YES	YES
Household FE	YES	YES	YES	YES
County FE	NO	NO	YES	YES
Province FE	NO	NO	NO	YES
Cluster robust standard errors	None	Village	Village	Village
Observations	5,262	5,262	5,262	5,262

Notes: Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

3.3. Robustness Test

First, we assessed the robustness of the estimation results using fixed effect models with various dimensions (Columns (1)–(3) in Table 3–Table 6). In Columns (1) and (2), we only controlled for time and province fixed effects, while the standard errors in Standard errors in Columns (1) were not clustered robust. Then, in Columns (3), we added the county fixed effect. The results showed that the coefficients of variables were similar in all columns. Moreover, the estimation results using a fixed effect model (Table A1) were similar to those in Table 3–Table 6. Therefore, the estimated results are robust.

Additionally, we replace expenditures with income in equation (2). Due to the endogeneity associated with income measurement error, an instrumental estimation of the fixed effect model is constructed using expenditure as an instrumental variable. The results in Table A2 are generally consistent with those in Table 3 – Table 6, supporting the robustness of our study.

3.4. Heterogeneity Effect across Income Strata

In addition to identifying the heterogeneity in pandemic impact across different income groups, we also examined how the pandemic impacted rural residents with different income levels. In this paper, the entire sample was divided into three categories based on the percentile of per capita income: low-, medium-, and high-income groups.

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Specifically, the low-income group consisted of households in the lowest 33% of income brackets, the high-income group consisted of households in the highest 33% of income brackets, and the middle-income bracket comprised the remainder. The estimation results for different income groups are shown in Table 7.

The estimation results show that the COVID-19 pandemic only had a significant and negative effect on the dietary energy intake in the low-income group at the 5% level of significance. An increase of 100 confirmed cases in a county resulted in a 2.02% (p<0.05) decrease in per capita dietary energy intake of the low-income rural residents. Furthermore, the fat intake of low- and high-income rural residents decreased by 2.31% (p<0.05) and 1.25% (p<0.05) for every 100 confirmed cases in a county, respectively.

Table 7. Estimation results of the COVID-19 impact on nutritional intake by income groups.

Dependent Variables	Low Income	Middle Income	High Income
ln*Dietary_Energy*	-0.0202**	-0.0113	-0.0123*
	(0.0094)	(0.0075)	(0.0064)
ln*Carbohydrate*	-0.0157*	-0.0099	-0.0104*
	(0.0083)	(0.0077)	(0.0058)
ln*Fat*	-0.0231**	-0.0125	-0.0125**
	(0.0091)	(0.0077)	(0.0055)
ln*Protein*	-0.0174*	-0.0041	-0.0051
	(0.0091)	(0.0069)	(0.0050)
Observations	1,754	1,754	1,754

Notes: For full estimation results, see supplementary materials (Table S1-Table S4); standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

4. Discussion

To the best of our knowledge, this paper is one of the first studies to investigate the COVID-19 pandemic's impact on the nutritional intake of China's rural residents. In order to prevent the spread of the virus, governments throughout China implemented a range of lockdown policies, including traffic control, production shut down, and restrictions on movement [46,50]. On the one hand, these measures disrupted agricultural production and food chain supplies and increased the cost of food storage and transportation [64,65]. On the other hand, disruptions in the supply of agricultural products, restrictions on human movement, and suspension of transportation and passenger transport caused the agricultural and non-farm incomes of rural residents to be reduced [66]. Additionally, rural residents' expected income decreased when faced with epidemic-induced uncertainty, and they were more likely to upsurge precautionary saving motives as a result [67]. As a result of these factors, there was a decrease in food availability, a decrease in farmers' willingness to consume, and consequently, a decrease in dietary energy intake. This provides an explanation for the main findings of this paper.

Further, since the negative effects of the COVID-19 pandemic on the intake of macronutrients differed, it is likely that the structure of the intake of macronutrients was altered as a result of the pandemic. The main reason why the nutritional structure changed was the changing structure of foods consumed. Thus, there was a relatively small decline in the consumption of carbohydrate-rich cereals as residents maintained their basic dietary needs. Meanwhile, fat-rich foods such as pork were consumed less frequently. Note that in 2020, China was also affected by the African swine fever outbreak, which contributed to a significant rise in pork prices and, to some extent, to a reduction in meat consumption. Using a time fixed effect, the impact of the African swine fever epidemic was controlled for in this study and thus did not affect our conclusions.

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The study also found that only low-income groups suffered significant and negative consequences in dietary energy intake from the COVID-19 pandemic. Since low-income groups have strong budget constraints and a high Engel coefficient, it was difficult to adjust the consumption structure when affected by the COVID-19 pandemic. Consequently, low-income households were less interchangeable across consumption types and food types. Under the influence of the pandemic, they could only reduce demand.

Several important policy implications are derived from the study. First, since the COVID-19 pandemic could exacerbate undernutrition among rural residents, particularly those with lower incomes, it is the government's responsibility to ensure that low-income rural residents have access to sufficient nutrition. Second, there needs to be attention given to nutritional balance and dietary balance in light of COVID-19. Third, it is important for the government to introduce supply-side policies to stabilize production, as well as provide policies to promote consumption and price stability to make the food system more resilient [68]. Finally, under the influence of the COVID-19, China's food security should focus on macro policy while focusing more on resident groups, families, and individuals.

It should be noted that our study has several limitations. First, the SAVE data contained only data regarding food consumption at home, which, despite being processed using equation (3), does not accurately reflect food consumption away from home. Second, because of the limitations of the SAVE data, COVID-19 can only be evaluated with regard to macronutrients, and its effect cannot be assessed on micronutrients such as vitamins and minerals. Third, studies have shown that farmers can increase production diversity in order to enrich dietary diversity [69], but this factor was not taken into consideration in this study. Accordingly, we suggest that future studies should concentrate on the effects of COVID-19 on food consumption away from home, micronutrients, and production diversity in rural China.

5. Conclusions

In conclusion, based on nationwide panel data and a fixed effect model, this paper provides insights into the nutritional intake of China's rural residents during the COVID-19 pandemic in 2020. We found that the COVID-19 pandemic negatively impacted the intake of dietary energy, carbohydrates, fats, and proteins. Furthermore, there was heterogeneity in the nutritional intake among different income groups, and only the dietary energy intake of the low-income group was significantly affected by the COVID-19 pandemic. Therefore, the government should assist low-income groups in accessing sufficient nutrition during the COVID-19 epidemic.

Supplementary Materials: Table S1: Estimation results of the COVID-19 impact on dietary energy intake by income groups. Table S2: Estimation results of the COVID-19 impact on carbohydrate intake by income groups. Table S3: Estimation results of the COVID-19 impact on fat intake by income groups. Table S4: Estimation results of the COVID-19 impact on protein intake by income groups.

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Appendix A

Table A1. Estimation results from the ordinary fixed effect model.

Dependent Variables	**ln*Energy***	**ln*Carbohydrate***	**ln*Fat***	**ln*Protein***
COVID	-0.0148***	-0.0146***	-0.0177***	-0.0123***
	(0.0035)	(0.0036)	(0.0035)	(0.0035)
Year2020	0.03***	0.03***	0.04***	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)
ln*Price_energy*	-0.48***			
	(0.02)			
ln*Price_ch*		-0.87***	0.09***	0.05**
		(0.02)	(0.02)	(0.02)
ln*Price_fat*		0.33***	-0.76***	0.31***
		(0.02)	(0.02)	(0.02)
ln*Price_pt*		0.16***	0.23***	-0.68***
		(0.04)	(0.03)	(0.03)
ln*Exp*	2.40***	2.50***	2.39***	2.36***
	(0.57)	(0.60)	(0.57)	(0.58)
$(\ln Exp)^2$	-0.11***	-0.11***	-0.11***	-0.11***
	(0.03)	(0.03)	(0.03)	(0.03)
Family_size	-0.04***	-0.05***	-0.05***	-0.04***
	(0.01)	(0.01)	(0.01)	(0.01)
Constant	-9.36***	-11.24***	-10.81***	-10.16***
	(2.97)	(3.09)	(2.95)	(2.97)
Household FE	Yes	Yes	Yes	Yes
Observations	5,262	5,262	5,262	5,262

Notes: Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A2. Estimation results from the instrumental fixed effect model.

Dependent Variables	ln*Energy*	ln*Carbohydrate*	ln*Fat*	ln*Protein*
COVID	-0.0233***	-0.0236***	-0.0260***	-0.0195***
	(0.0081)	(0.0089)	(0.0083)	(0.0073)
Year2020	0.06***	0.06***	0.06***	0.04***
	(0.01)	(0.02)	(0.01)	(0.01)
ln*Price_energy*	-0.50***			
	(0.04)			
ln*Price_ch*		-0.77***	0.18***	0.13***
		(0.06)	(0.05)	(0.05)
ln*Price_fat*		0.33***	-0.75***	0.31***
		(0.05)	(0.05)	(0.04)
ln*Price_pt*		-0.01	0.07	-0.82***
		(0.10)	(0.09)	(0.08)
ln*Inc*	0.50***	0.56***	0.52***	0.44***
	(0.15)	(0.17)	(0.16)	(0.14)
Family_size	0.05	0.06*	0.05*	0.04
	(0.03)	(0.03)	(0.03)	(0.03)
Household FE	Yes	Yes	Yes	Yes
Cragg-Donald Wald F Statistics	13.80	14.15	14.15	14.15
Observations	5,262	5,262	5,262	5,262

Notes: Standard errors in parentheses; The Stock-Yogo weak ID test critical value (15% maximal IV size) is 8.96; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

References

1. Lurie, N.; Keusch, G.T.; Dzau, V.J. Urgent lessons from COVID 19: why the world needs a standing, coordinated system and sustainable financing for global research and development. *Lancet* **2021**, *397*, 1229-1236, doi:https://doi.org/10.1016/S0140-6736(21)00503-1.
2. Guan, W.; Ni, Z.; Hu, Y.; Liang, W.; Ou, C.; He, J.; Liu, L.; Shan, H.; Lei, C.; Hui, D.S.C.; et al. Clinical Characteristics of Coronavirus Disease 2019 in China. *N. Engl. J. Med.* **2020**, *382*, 1708-1720, doi:10.1056/NEJMoa2002032.
3. Wu, Z.Y.; McGoogan, J.M. Characteristics of and Important Lessons From the Coronavirus Disease 2019 (COVID-19) Outbreak in China Summary of a Report of 72 314 Cases From the Chinese Center for Disease Control and Prevention. *JAMA-J. Am. Med. Assoc.* **2020**, *323*, 1239-1242, doi:10.1001/jama.2020.2648.
4. WHO. WHO Coronavirus (COVID-19) Dashboard. Available online: https://covid19.who.int/ (accessed on 13 May 2022).
5. Deaton, A. COVID-19 and Global Income Inequality. *LSE Public Policy Review* **2021**, *1*, 1-10, doi:http://doi.org/10.31389/lseppr.26.
6. Beckman, J.; Countryman, A.M. The Importance of Agriculture in the Economy: Impacts from COVID-19. *Am. J. Agr. Econ.* **2021**, *103*, 1595-1611, doi:https://doi.org/10.1111/ajae.12212.
7. Song, L.G.; Zhou, Y.X. The COVID-19 Pandemic and Its Impact on the Global Economy: What Does It Take to Turn Crisis into Opportunity? *China World Econ.* **2020**, *28*, 1-25, doi:10.1111/cwe.12349.
8. Cheng, A.; Chen, T.; Jiang, G.; Han, X. Can Major Public Health Emergencies Affect Changes in International Oil Prices? *Int. J. Environ. Res. Public Health* **2021**, *18*, doi:10.3390/ijerph182412955.
9. Laborde, D.; Martin, W.; Swinnen, J.; Vos, R. COVID-19 risks to global food security. *Science* **2020**, *369*, 500-502, doi:doi:10.1126/science.abc4765.
10. Fan, S.; Si, W.; Zhang, Y. How to prevent a global food and nutrition security crisis under COVID-19? *China Agric. Econ. Rev.* **2020**, *12*, 471-480, doi:10.1108/CAER-04-2020-0065.
11. FAO; IFAD; UNICEF; WFP; WHO. *The State of Food Security and Nutrition in the World 2021: Transforming food systems for food security, improved nutrition and affordable healthy diets for all*; FAO: Rome, Italy, 2021.
12. Ahmed, F.; Islam, A.; Pakrashi, D.; Rahman, T.; Siddique, A. Determinants and dynamics of food insecurity during COVID-19 in rural Bangladesh. *Food Policy* **2021**, *101*, doi:10.1016/j.foodpol.2021.102066.

13. Nechifor, V.; Ramos, M.P.; Ferrari, E.; Laichena, J.; Kihiu, E.; Omanyo, D.; Musamali, R.; Kiriga, B. Food security and welfare changes under COVID-19 in Sub-Saharan Africa: Impacts and responses in Kenya. *Glob. Food Sec.* **2021**, *28*, doi:10.1016/j.gfs.2021.100514.
14. Bundervoet, T.; Dávalos, M.E.; Garcia, N. The short-term impacts of COVID-19 on households in developing countries: An overview based on a harmonized dataset of high-frequency surveys. *World Dev.* **2022**, *153*, doi:10.1016/j.worlddev.2022.105844.
15. Carducci, B.; Keats, E.C.; Ruel, M.; Haddad, L.; Osendarp, S.J.M.; Bhutta, Z.A. Food systems, diets and nutrition in the wake of COVID-19. *Nat. Food* **2021**, *2*, 68-70, doi:10.1038/s43016-021-00233-9.
16. Garnett, P.; Doherty, B.; Heron, T. Vulnerability of the United Kingdom's food supply chains exposed by COVID-19. *Nat. Food* **2020**, *1*, 315-318, doi:10.1038/s43016-020-0097-7.
17. Popescu, G.C.; Popescu, M. COVID-19 pandemic and agriculture in Romania: effects on agricultural systems, compliance with restrictions and relations with authorities. *Food Secur.* **2022**, *14*, 557-567, doi:10.1007/s12571-021-01239-8.
18. Ruan, J.; Cai, Q.; Jin, S. Impact of COVID‐19 and nationwide lockdowns on vegetable prices: evidence from wholesale markets in China. *Am. J. Agr. Econ.* **2021**, *103*, 1574-1594.
19. Goeb, J.; Zone, P.P.; Kham Synt, N.L.; Zu, A.M.; Tang, Y.; Minten, B. Food prices, processing, and shocks: Evidence from rice and COVID-19. *J. Agric. Econ.* **2021**, doi:10.1111/1477-9552.12461.
20. Dietrich, S.; Giuffrida, V.; Martorano, B.; Schmerzeck, G. COVID-19 policy responses, mobility, and food prices. *Am. J. Agr. Econ.* **2022**, *104*, 569-588, doi:10.1111/ajae.12278.
21. Yu, X.; Liu, C.; Wang, H.; Feil, J.H. The impact of COVID-19 on food prices in China: evidence of four major food products from Beijing, Shandong and Hubei Provinces. *China Agric. Econ. Rev.* **2020**, *12*, 445-458, doi:10.1108/CAER-04-2020-0054.
22. Falkendal, T.; Otto, C.; Schewe, J.; Jägermeyr, J.; Konar, M.; Kummu, M.; Watkins, B.; Puma, M.J. Grain export restrictions during COVID-19 risk food insecurity in many low- and middle-income countries. *Nat. Food* **2021**, *2*, 11-14, doi:10.1038/s43016-020-00211-7.
23. Amare, M.; Abay, K.A.; Tiberti, L.; Chamberlin, J. COVID-19 and food security: Panel data evidence from Nigeria. *Food Policy* **2021**, *101*, 102099, doi:https://doi.org/10.1016/j.foodpol.2021.102099.
24. Tabe-Ojong, M.P.J.; Gebrekidan, B.H.; Nshakira-Rukundo, E.; Börner, J.; Heckelei, T. COVID-19 in rural Africa: Food access disruptions, food insecurity and coping strategies in Kenya, Namibia, and Tanzania. *Agric. Econ.* **2022**, doi:10.1111/agec.12709.
25. Maredia, M.K.; Adenikinju, A.; Belton, B.; Chapoto, A.; Faye, N.F.; Liverpool-Tasie, S.; Olwande, J.; Reardon, T.; Theriault, V.; Tschirley, D. COVID-19's impacts on incomes and food consumption in urban and rural areas are surprisingly similar: Evidence from five African countries. **2022**, *33*, doi:10.1016/j.gfs.2022.100633.
26. Huber, B.C.; Steffen, J.; Schlichtiger, J.; Brunner, S. Altered nutrition behavior during COVID-19 pandemic lockdown in young adults. *Eur J Nutr* **2021**, *60*, 2593-2602, doi:10.1007/s00394-020-02435-6.
27. Mahmud, M.; Riley, E. Household response to an extreme shock: Evidence on the immediate impact of the Covid-19 lockdown on economic outcomes and well-being in rural Uganda. **2021**, *140*, doi:10.1016/j.worlddev.2020.105318.
28. Gupta, A.; Zhu, H.; Doan, M.K.; Michuda, A.; Majumder, B. Economic Impacts of the COVID−19 Lockdown in a Remittance-Dependent Region. *Am. J. Agr. Econ.* **2021**, *103*, 466-485, doi:https://doi.org/10.1111/ajae.12178.
29. Fan, S.; Teng, P.; Chew, P.; Smith, G.; Copeland, L. Food system resilience and COVID-19 – Lessons from the Asian experience. *Glob. Food Sec.* **2021**, *28*, 100501, doi:https://doi.org/10.1016/j.gfs.2021.100501.
30. Hirvonen, K.; de Brauw, A.; Abate, G.T. Food Consumption and Food Security during the COVID-19 Pandemic in Addis Ababa. *Am. J. Agr. Econ.* **2021**, *103*, 772-789, doi:https://doi.org/10.1111/ajae.12206.
31. Ceballos, F.; Hernandez, M.A.-O.; Paz, C. Short-term impacts of COVID-19 on food security and nutrition in rural Guatemala: Phone-based farm household survey evidence.
32. Harris, J.; Nguyen, P.H.; Tran, L.M.; Huynh, P.N. Nutrition transition in Vietnam: Changing food supply, food prices, household expenditure, diet and nutrition outcomes. *Food Secur.* **2020**, *12*, 1141-1155.
33. Murphy, B.; Benson, T.; McCloat, A.; Mooney, E.; Elliott, C.; Dean, M.; Lavelle, F. Changes in Consumers' Food Practices during the COVID-19 Lockdown, Implications for Diet Quality and the Food System: A Cross-Continental Comparison. *Nutrients* **2021**, *13*, doi:10.3390/nu13010020.
34. Visser, M.; Schaap, L.A.; Wijnhoven, H.A.H. Self-Reported Impact of the COVID-19 Pandemic on Nutrition and Physical Activity Behaviour in Dutch Older Adults Living Independently. *Nutrients* **2020**, *12*, doi:10.3390/nu12123708.
35. Gallo, L.A.-O.; Gallo, T.F.; Young, S.L.; Moritz, K.M.; Akison, L.K. The Impact of Isolation Measures Due to COVID-19 on Energy Intake and Physical Activity Levels in Australian University Students. LID - 10.3390/nu12061865 [doi] LID - 1865.
36. Mayasari, N.A.-O.; Ho, D.K.N.; Lundy, D.J.; Skalny, A.V.; Tinkov, A.A.; Teng, I.C.; Wu, M.C.; Faradina, A.; Mohammed, A.Z.M.; Park, J.M.; et al. Impacts of the COVID-19 Pandemic on Food Security and Diet-Related Lifestyle Behaviors: An Analytical Study of Google Trends-Based Query Volumes. LID - 10.3390/nu12103103 [doi] LID - 3103.
37. Min, S.; Xiang, C.; Zhang, X.-h. Impacts of the COVID-19 pandemic on consumers' food safety knowledge and behavior in China. *J. Integr. Agric.* **2020**, *19*, 2926-2936, doi:https://doi.org/10.1016/S2095-3119(20)63388-3.
38. Attwood, S.; Hajat, C. How will the COVID-19 pandemic shape the future of meat consumption? *Public Health Nutr* **2020**, *23*, 3116-3120, doi:10.1017/S136898002000316X.
39. Qi, X.; Ploeger, A. Explaining Chinese Consumers' Green Food Purchase Intentions during the COVID-19 Pandemic: An Extended Theory of Planned Behaviour. *Foods* **2021**, *10*, 1200.
40. Chang, H.-H.; Meyerhoefer, C.D. COVID-19 and the Demand for Online Food Shopping Services: Empirical Evidence from Taiwan. *Am. J. Agr. Econ.* **2021**, *103*, 448-465, doi:https://doi.org/10.1111/ajae.12170.

41. Guo, H.; Liu, Y.; Shi, X.; Chen, K.Z. The role of e-commerce in the urban food system under COVID-19: lessons from China. *China Agric. Econ. Rev.* **2021**, *13*, 436-455, doi:10.1108/CAER-06-2020-0146.
42. Wang, H.H.; Hao, N. Panic buying? Food hoarding during the pandemic period with city lockdown. *J. Integr. Agric.* **2020**, *19*, 2916-2925, doi:https://doi.org/10.1016/S2095-3119(20)63448-7.
43. Li, S.; Kallas, Z.; Rahmani, D.; Gil, J.M. Trends in food preferences and sustainable behavior during the COVID-19 lockdown: Evidence from Spanish consumers. *Foods* **2021**, *10*, doi:10.3390/foods10081898.
44. Yang, X. Potential consequences of COVID-19 for sustainable meat consumption: the role of food safety concerns and responsibility attributions. *Br. Food J.* **2021**, *123*, 455-474, doi:10.1108/BFJ-04-2020-0332.
45. Muresan, I.C.; Harun, R.; Arion, F.H.; Brata, A.M.; Chereches, I.A.; Chiciudean, G.O.; Dumitras, D.E.; Oroian, C.F.; Tirpe, O.P. Consumers' attitude towards sustainable food consumption during the covid-19 pandemic in Romania. *Agriculture (Switzerland)* **2021**, *11*, doi:10.3390/agriculture11111050.
46. Zhang, Y.; Diao, X.; Chen, K.Z.; Robinson, S.; Fan, S. Impact of COVID-19 on China's macroeconomy and agri-food system – an economy-wide multiplier model analysis. *China Agric. Econ. Rev.* **2020**, *12*, 387-407, doi:10.1108/CAER-04-2020-0063.
47. Luo, R.-f.; Liu, C.-f.; Gao, J.-j.; Wang, T.-y.; Zhi, H.-y.; Shi, P.-f.; Huang, J.-k. Impacts of the COVID-19 pandemic on rural poverty and policy responses in China. *J. Integr. Agric.* **2020**, *19*, 2946-2964, doi:https://doi.org/10.1016/S2095-3119(20)63426-8.
48. Cui, Y.; Si, W.; Zhao, Q.R.; Glauben, T.; Feng, X.L. The Impact of COVID-19 on the Dietary Diversity of Children and Adolescents: Evidence from a Rural/Urban Panel Study. *China World Econ.* **2021**, *29*, 53-72, doi:10.1111/cwe.12394.
49. Zhao, A.; Li, Z.; Ke, Y.; Huo, S.; Ma, Y.; Zhang, Y.; Zhang, J.; Ren, Z. Dietary diversity among chinese residents during the COVID-19 outbreak and its associated factors. *Nutrients* **2020**, *12*, 1-13, doi:10.3390/nu12061699.
50. Tian, X.; Zhou, Y.; Wang, H. The Impact of COVID-19 on Food Consumption and Dietary Quality of Rural Households in China. *Foods* **2022**, *11*, doi:10.3390/foods11040510.
51. Han, X.; Xue, P.; Zhang, N. Impact of Grain Subsidy Reform on the Land Use of Smallholder Farms: Evidence from Huang-Huai-Hai Plain in China. *Land* **2021**, *10*, 929.
52. Xue, P.; Han, X.; Elahi, E.; Zhao, Y.; Wang, X. Internet Access and Nutritional Intake: Evidence from Rural China. *Nutrients* **2021**, *13*, 2015.
53. Yang, Y.; Wang, G.; Pan, X. *China Food Composition*; Peking University Medical Press: Beijing, China, 2009; Volume 2nd ed.
54. Li, G.; Chen, Y. An Analysis of the Impact of Income Growth on Nutrition Demand: Evidence from Urban Households in Guangdong Province [in Chinese]. *Economic Science* **2017**, 60-72.
55. Zheng, Z.; Henneberry, S.R. Estimating the impacts of rising food prices on nutrient intake in urban China. *China Econ. Rev.* **2012**, *23*, 1090-1103, doi:https://doi.org/10.1016/j.chieco.2012.07.001.
56. Deaton, A.; Muellbauer, J. *Economics and Consumer Behavior*; Cambridge University Press: Cambridge, 1980.
57. Jensen, R.T.; Miller, N.H. The impact of food price increases on caloric intake in China. *Agric. Econ.* **2008**, *39*, 465-476.
58. Green, R.; Cornelsen, L.; Dangour, A.D.; Turner, R.; Shankar, B.; Mazzocchi, M.; Smith, R.D. The effect of rising food prices on food consumption: systematic review with meta-regression. *Bmj* **2013**, *346*.
59. Elleby, C.; Domínguez, I.P.; Adenauer, M.; Genovese, G. Impacts of the COVID-19 pandemic on the global agricultural markets. *Environ Resour Econ (Dordr)* **2020**, *76*, 1067-1079.
60. Han, X.; Chen, Y. Food consumption of outgoing rural migrant workers in urban area of China: a QUAIDS approach. *China Agric. Econ. Rev.* **2016**, *8*, doi:10.1108/CAER-06-2015-0067.
61. Han, X.; Yang, S.; Chen, Y.; Wang, Y. Urban segregation and food consumption. *China Agric. Econ. Rev.* **2019**, *11*, 583-599, doi:10.1108/CAER-07-2018-0153.
62. Zhu, W.-b.; Chen, Y.-f.; Zhao, J.; Wu, B.-b. Impacts of household income on beef at-home consumption: Evidence from urban China. *J. Integr. Agric.* **2021**, *20*, 1701-1715, doi:https://doi.org/10.1016/S2095-3119(20)63582-1.
63. Bureau of Disease Prevention and Control of National Health Commission of the PRC. *Report on the Nutrition and Chronic Disease Status of Chinese Residents*; Peoples' Medical Publishing House: Beijing, 2020.
64. Min, S.; Zhang, X.; Li, G. A snapshot of food supply chain in Wuhan under the COVID-19 pandemic. *China Agric. Econ. Rev.* **2020**.
65. Wang, Y.; Wang, J.; Wang, X. COVID-19, supply chain disruption and China's hog market: a dynamic analysis. *China Agric. Econ. Rev.* **2020**.
66. Long, W.; Zeng, J.; Sun, T. Who Lost Most Wages and Household Income during the COVID - 19 Pandemic in Poor Rural China? *China World Econ.* **2021**, *29*, 95-116.
67. Ning, L.; Wang, Y. Quantitative analysis of the COVID-19 pandemic shock to household consumption in China. *Front. Econ. China* **2020**, *15*, 355-379, doi:10.3868/s060-011-020-0015-4.
68. Hertel, T.; Elouafi, I.; Tanticharoen, M.; Ewert, F. Diversification for enhanced food systems resilience. *Nat. Food* **2021**, *2*, 832-834, doi:10.1038/s43016-021-00403-9.
69. Sibhatu, K.T.; Qaim, M. Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. *Food Policy* **2018**, *77*, 1-18, doi:https://doi.org/10.1016/j.foodpol.2018.04.013.