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The effect of income inequality on nutritional outcomes: Evidence from rural China

Abstract. There are growing concerns about income inequality and health, while little is known about the relationship between income inequality and nutritional outcomes, especially in a transition economy like China. To fill this gap, the aim of this study is to explore the effect of income inequality on the nutritional outcomes of Chinese farmers, including body mass index (BMI), underweight, overweight and obesity statuses. Methodologically this study relies on the theoretical propositions of both income hypothesis and agricultural economics. Specifically, this study compares the literature examining income inequality, then analyses the possible effects of income inequality on the nutritional outcomes of Chinese farmers, and finally tests the results of the analysis using econometric models. Using data from the China Health and Nutrition Survey (CHNS) from 2015, we found that the relationship between income and BMI shifted from positive to negative with rapid growth in per capita household incomes and that higher income inequality can significantly increase the risk of being overweight or obese among low-income groups. In particular, the effect of income inequality on overweight and obesity is higher for males, while its effect tends to be negligible for females. The findings in this study are proved to be robust. Therefore, several policy implications for meeting the challenges concerning income inequality and improving nutritional outcomes for Chinese farmers are also discussed.

Keywords: income inequality; rural development; nutritional outcomes; body mass index (BMI); population health; transition economy; China.

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Introduction

Income has been well-documented as one of the most important determinants of nutrition-related health, which is particularly true in a transition economy like China; yet, less attention has been paid to the role of income inequality. China has recorded impressive growth over the past decades, and since the introduction of its market economy, people's living standards and dietary quality have increased dramatically. However, there is a growing concern about income inequality **[Asiseh, Yao, 2016, p. 2; Li, Zhu, 2006, p. 668]**. According to the estimation from the World Bank and National Bureau of Statistics of China[1], China's Gini coefficient increased rapidly from 0.28 in 1981 to 0.49 in 2008, and reached 0.47 in 2017 **[Yao, Asiseh, 2019, p. 24]**. As a result of China's policy of giving priority to efficiency and cities, a small group of people became rich quickly, but low-income groups benefited little, especially in rural areas **[Cai et al., 2021, p. 3]**. The rich are becoming richer and the poor are becoming poorer, which may reduce socioeconomic mobility, undermine the flexible class structure in the countryside and negatively affect Chinese farmers. The Chinese government has been aware of the potential harm income inequality can cause in rural China and has implemented some policies to reduce it, such as China's poverty alleviation policies, which will enable the entire Chinese population to be lifted out of absolute poverty by 2021. However, the issue of income inequality will remain an important challenge for China's rural development for the foreseeable future. Therefore, studying income inequality in China is necessary for both Chinese farm households and policy makers looking to improve the welfare of rural residents.

Significant structural changes have been observed in household income and dietary patterns in China, and a comprehensive understanding of the effect of income inequality on nutritional outcomes is required. China's per capita national income (GNI) grew rapidly from 1,209.46 US dollars in 1995 to 8,222.96 US dollars in 2019, closing in on the average of 8,349.30 US dollars for upper-middle-income countries, and it is still showing

[1] National Bureau of Statistics of China. (2018). China Yearbook of Household Survey. China Statistics Press, p. 523.

a rapidly rising trend[1]. Against this background, the strong effect of budget constraints on the food consumption of Chinese farmers will be muted by the substantial increases in their incomes. Thus, the effect of income inequality on Chinese farmers' nutritional outcomes differs from that of both developed and some developing countries. At the same time, the diets of Chinese farmers have changed dramatically. For example, Chinese farmers are shifting away from the consumption of traditional Chinese foods featuring grains and vegetables to foods that are high in fat and protein **[Ren, Li, Wang, 2019, p. 59]**. Sweeter and more animal-derived foods are also being favoured by more Chinese people **[Jolliffe, 2011, p. 11]**. These changes will also alter the effect of income inequality on low- and high-income groups. China is a typical transition economy, and this study examines the effect of income inequality on the nutritional intake of the rural population in China, which has important implications not only for farmers and policy makers in China but also for those in other transition economies.

In this study, we present how income inequality affects farmers' nutritional health in terms of both the absolute income hypothesis and the relative income hypothesis. The absolute income hypothesis suggests that higher income groups tend to have better health and nutritional outcomes. In other words, the absolute income hypothesis suggests that farmers' personal health and income are concave, and that people with higher income may have lower risk of overweight and obesity. According to this hypothesis, higher income groups have a greater ability to purchase higher quality food and therefore have better food consumption and nutritional intake choices, and unhealthy and poor nutritional outputs are the result of low or extreme poverty. Within the same group, rising income inequality means that more wealth is taken by fewer people, which is good for the health and nutritional outcomes of the rich but bad for the poor, and the impact on the group as a whole is uncertain.

The relative income hypothesis states that health depends on an individual's income relative to others in his or her group, rather than an individual's absolute income, and that an individual's relative rank in the group is correlated with health and nutritional outcomes. This hypothesis suggests that relative income is more representative of an individual's ability to obtain goods and services in the same community, and that these things are often correlated with an individual's health and nutritional outcomes. Besides, a number of psychological and psychiatric factors can have a significant impact on an individual's health and nutritional outcomes. For example, relative poverty compared to people in the same community can cause people to feel stressed and depressed, which can affect the individual's state of health. According to the relative income hypothesis, an increase in income inequality within the same group will result in fewer people with higher incomes and more people with lower incomes, which will be detrimental to the

[1] World Bank. (2021). The data are from the World Bank Database (2010 Constant US dollars). https://data.worldbank.org.cn/ indicator/NY.GNP.PCAP.KD?locations=CN.

nutrition and health status of individuals. Moreover, this hypothesis also suggests that the harm caused by income inequality occurs mainly among low-income groups.

Based on the absolute and relative income hypotheses, many articles have discussed the effects of income inequality on nutrition and health. However, most of the existing studies on the effect of income inequality on health and nutrition are exclusively based on samples from developed countries, while their findings are mixed and may not be applicable to transition economies like China **[Du et al., 2004, p. 1506; Ren et al., 2021, p. 2]**. Using individual-level data from the Behavioural Risk Factor Surveillance System collected during 1996–1998, Chang and Christakis **[2005, p. 90]** do not find a positive association between income inequality and weight outcomes, such as body mass index (BMI) and the odds of being obese. Nikolaou and Nikolaou **[2008, p. 405]** argue that in European Union countries, income inequality mainly affects women, especially middle-aged women, rather than men. However, Pickett and Wilkinson **[2015, p. 318]** analysed income inequality and child welfare in 23 wealthy countries. Their findings show that income inequality has a negative effect on many aspects of child welfare, such as teenage homicides, infant mortality rates, low birth weights, educational performance, high school dropouts, overweight and mental health problems **[Pickett, Wilkinson, 2015, p. 317]**. Bjornstrom **[2011, p. 113]**, Matthew and Brodersen **[2018, p. 438]** also support the idea that income inequality increases the risk of obesity in American adults. Considering that systematic differences exist between developed and developing countries in terms of the level of medical care, consumers' dietary knowledge, income distribution systems and food culture **[Min, Wang, Yu, 2021, p. 2]**, there are also differences in the effect of income inequality on nutritional outcomes. For instance, individuals living in developed countries have higher absolute income levels, so for most farms, budget constraints will not be a major factor affecting their access to food and nutrition **[Ren et al., 2019, p. 1753]**. However, for the low-income class in developing countries, budget constraints may significantly affect the food consumption and nutritional intake of many farmers, so income and income inequality may have different effects across different economies.

While a considerable number of studies have investigated the consequences of income inequality in China, little is known about its effect on nutritional outcomes, especially in rural areas of the country. Several papers have used the Gini coefficient as a proxy variable for income inequality to examine the effect of income inequality on Chinese farmers' health statuses, such as individual mental health scores **[Chen, Meltzer, 2008, p. 2207]**, personal health self-assessments **[Li, Zhu, 2006, p. 680]** and chronic diseases, such as hypertension and diabetes **[Chen, Meltzer, 2008, p. 2208]**. Other studies have discussed the channels through which relative poverty indices affect individuals' mental health statuses, and they include social relationships, general trust and self-confidence **[Bakkeli, 2016, p. 40]**. However, these studies have mainly focused on the effect of income inequality on health status and neglected the effect it has on nutritional outcomes. Moreover, most of the existing literature uses aggregate indices to represent income inequality, such

as the Gini coefficient at the county or community level, which ignores the heterogeneity of the effects of income inequality on individual nutritional outcomes.

Using the absolute income hypothesis, relative income hypothesis, and agricultural economics as theoretical propositions, the purpose of this study includes the following three points. In the first place, the study aims to understand the current state of income inequality in rural China and the relationship between income inequality and nutritional outcomes in a transition country like China. Unlike the existing literature centred on developed economies, this study focuses on the effect of income inequality on nutritional outcomes in a transition economy such as China, which contributes to enriching the literature by examining the topic of income inequality and nutritional outcomes. Second, the study aims to test whether the hypothesis that income inequality has a greater impact on low-income groups is appropriate for Chinese farmers. This question needs to take into account the individual heterogeneity of farm households; therefore, we use the individual relative deprivation index instead of the aggregate index to express income inequality, thereby overcoming the limitation of the aggregate index with regard to ignoring individual heterogeneity. Third, the study aims to bring more attention to the problem of income inequality among Chinese farmers through our research and to make some targeted suggestions for the Chinese government to deal with this problem, thus promoting the nutrition and welfare of Chinese farmers while also providing some experiences for other transition countries to deal with the problem of income inequality.

Econometric models

In order to explore the relationship between nutritional outcomes and income inequality, we started with a linear regression for BMI as the benchmark model. Afterward, a multinomial logistic regression model was applied for four BMI categories: underweight, normal weight, overweight and obesity. Finally, a probit model was applied to further check the robustness of our results.

The benchmark model. As mentioned above, BMI is one of the most important indicators of individual nutritional outcomes, and it may be influenced by income inequality. At the same time, farmers' and household characteristics are also important factors affecting BMI, so we followed the studies of Li and Zhu [2006, p. 673] and Ren et al. [2019, p. 1756], and the baseline model for this study was established, as shown in the equation:

$$BMI_k = \alpha_0 + \beta_1 R_k + \beta_2 I_k + \beta_3 H_k + \varepsilon_k, \quad (1)$$

where, BMI_k is the BMI of farmer K, and it is calculated by dividing the body mass by the height squared (kg/m^2); R_k is the index measuring the income inequality of farmer K, including the ranking of individual income in the community, the Yitzhaki index and the Kakwani index; I_k is the vector indicating farmers' characteristics, including age, the quadratic term of age, gender, marital status, working situation and physical activity; H_k represents the household control variables, including household size, household per

capita income and the quadratic term of household per capita income; ε_k is the disturbance term and is assumed to be normally distributed. We are interested in the coefficient of the income inequality variable (β_1). If it is significantly positive, we can conclude that income inequality increases BMI.

The multinomial logistic model. As BMI alone cannot determine whether an individual's nutritional outcome is healthy or not, we further classified individuals' BMIs into four categories – underweight, normal weight, overweight and obese[1] – to further estimate the effect of income inequality on nutritional outcomes. In China, though overnutrition is an emerging public health issue and related to overweight and obesity, it is estimated that approximately 150.8 million people are undernourished, especially in rural areas[2]. The available research on the nutritional effects of income inequality exclusively focuses on the issue of overnutrition, and less attention has been paid to undernutrition **[Hong, Hong, 2007, p. 60]**. We also aimed to examine whether income inequality has an effect on the risk of being underweight, overweight or obese, using normal weight as the reference group. Since our dependent variables are multi-categorical, the ordinary least squares (OLS) method was not appropriate. Therefore, we used a multinomial logistic model to analyse the effect of income inequality on underweight, overweight and obesity. The model is defined as follows:

$$\begin{cases} \ln(P_1/P_2) = \alpha_1 + \beta_{11}R_k + \beta_{12}I_k + \beta_{13}H_k + \varepsilon_k; \\ \ln(P_3/P_2) = \alpha_2 + \beta_{21}R_k + \beta_{22}I_k + \beta_{23}H_k + \varepsilon_k; \\ \ln(P_4/P_2) = \alpha_3 + \beta_{31}R_k + \beta_{32}I_k + \beta_{33}H_k + \varepsilon_k, \end{cases} \quad (2)$$

where P_1, P_2, P_3 and P_4 represent the probability of being underweight, normal weight, overweight and obese, respectively, and the vectors R_k, I_k and H_k are the same as those used in model (1). In this case, the maximum likelihood method is used to estimate the parameters to be calculated using equation (2).

We are interested in the coefficients of the income inequality variable (β_{11},β_{21},β_{31}). If they are significantly positive, we can conclude that income inequality may worsen nutritional outcomes by increasing the risk of being underweight, overweight or obese. The lower the income, the greater the individual deprivation index **[Li, Zhu, 2006, p. 687]**, and this will result in the lower income group suffering from a higher risk of being underweight, overweight or obese.

The probit model. To further check the robustness of our estimation results, we also defined the nutritional outcomes as a binary outcome: being overweight/obese or otherwise. This is a common strategy in empirical studies [Morris, 2007, p. 415]. The probit model is applied as follows:

$$Probit(Y_k = 1) = \beta_1 R_k + \beta_2 I_k + \beta_3 H_k + \varepsilon_k, \quad (3)$$

[1] The detailed classification is given in section describing the variables.
[2] UN World Food Programme. China. https://www.wfp.org/countries/china.

where the dependent variable Y_k is a binary variable; it equals 1 if the *Kth* individual is overweight or obesity and 0 otherwise; the vectors R_k, I_k and H_k are the same variables as those used in models (1) and (2); the random error term ε_k is assumed to follow a normal distribution. We used the maximum likelihood estimation method to estimate the relevant parameters. If the sign of the coefficient of income inequality in the three models is the same, all positive or all negative, and there is little difference in the significance level, then our result is robust; otherwise, it is not robust.

Data and variables

The sample. We used data from the China Health and Nutrition Survey (CHNS). The CHNS was designed to study health and nutrition-related issues in China and was conducted under an international collaborative project between the National Institute of Nutrition and Food Safety of the Chinese Centre for Disease Control and Prevention and the Carolina Population Centre at the University of North Carolina in Chapel Hill. The CHNS was first carried out in 1989 and since then, another nine waves were conducted in 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011 and 2015 in nine provinces, namely Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning and Shandong (since 2011, three additional municipal cities have been included: Beijing, Chongqing and Shanghai), which vary substantially in terms of their geography, economic development and public resources, as well as with regard to health indicators. The CHNS data include detailed information about the characteristics of the households and individuals surveyed, as well as health-related information, such as that concerning physical conditions, healthy behaviours and nutritional intake. We used the most recent data from 2015 for our analysis.

CHNS2015 covers 12 provinces of China (Heilongjiang, Liaoning, Jiangsu, Shandong, Henan, Hubei, Hunan, Guangxi, Guizhou, Shaanxi, Yunnan and Zhejiang) and 3 autonomous cities (Beijing, Shanghai and Chongqing), with a total of 360 communities and 20,914 people. Our sample is limited to all adults aged 18 to 70 at the time of the survey and provides a complete set of data on individual demographics and household characteristics (age, gender, education, marital status, whether they work, physical activities, household size and household income). Since we needed to construct an index of income inequality, non-positive reports of household income were eliminated. Consequently, our final sample consisted of 6,379 observations (Table 1).

Dependent variables. As aforementioned, our main dependent variables are nutritional outcomes, which are measured using BMI and the four binary variables of being underweight, normal weight, overweight or obese. BMI is calculated by dividing the body mass by the height squared (kg/m^2). According to the criteria proposed by the World Health Organisation[1], a BMI below 18.5 is defined as

[1] WHO. (2000). Obesity: Preventing and managing the global epidemic. Report on a WHO consultation. WHO Technical Report Series 894. World Health Organization, Geneva, p. 28.

Table 1. **Variable definitions and descriptive statistics**

Variable	Definition	All	Females	Males	Difference
Dependent variables					
BMI	Weight/height^2	24.368	24.236	24.512	–0.276***
Underweight	1 if the individual is underweight, 0 otherwise	0.028	0.032	0.024	0.007*
Normal weight	1 if the individual is normal weight, 0 otherwise	0.481	0.488	0.475	0.013
Overweight	1 if the individual is overweight, 0 otherwise	0.490	0.480	0.501	–0.020
Obesity	1 if the individual is obese, 0 otherwise	0.155	0.153	0.157	–0.004
Independent variables					
Rank	Rank (incomes in descending order) in the community	20.918	21.225	20.583	0.642**
Yitzhaki index	Yitzhaki = $\Sigma(y_i–y_j)/N$, for all $y_i > y_j$ where y_i is the income of person I and N is the size of the community	12.605	12.994	12.180	0.814***
Kakwani index	Yitzhaki/μ_k, μ_k is the mean of Yitzhaki in the community	1.000	1.026	0.971	0.055***
Control variables					
Age	Age in years	47.740	47.862	47.607	0.254
Age squared	Age squared	2456.066	2464.716	2450.014	14.702
Gender	Male = 1; Female = 0	0.478	0.00	1.00	–1.00
Education	Years of education	9.896	9.143	10.718	–1.575***
Marital status	1 if the individual is married, 0 otherwise	0.875	0.889	0.859	0.029***
Occupation	1 if the individual is currently working, 0 otherwise	0.563	0.460	0.676	–0.217***
Physical activities	1 if the individual's work requires heavy physical activities[1], 0 otherwise	0.182	0.134	0.235	–0.101***
Income	Per capita household income adjusted to 2015 price index (1000 CNY)	29.128	28.007	30.309	–2.303**
Household size	The total number of household members	4.864	4.911	4.813	0.098*
Observations	The number of observations	6,379	6,379	6,379	6,379

Note: *, ** and *** denote the statistical significance at the 10 %, 5 % and 1 % levels, respectively.
Source: own estimations using the CHNS data (2015).

[1] Jobs that involve heavy physical activity include being a steel worker, lumber worker, mason, farmer, athlete and dancer.

underweight, a BMI equal to 25 or more is considered overweight and a BMI greater than or equal to 30 means that the individual is obese. However, Wu [2006, p.363] believes that this classification from the WHO is commonly used for Western people but that it is not applicable to China. Therefore, we follow Zhou [2002, p. 247] and Ren et al. [2019, p. 1757] in defining people with BMIs less than 18 as underweight, BMIs greater than or equal to 24 as overweight and BMIs greater than 28 as obese [Zhou, 2002, p. 246].

The summary statistics of the main dependent variables are presented in Table 1. It shows that the average BMI is more than 24 for the pooled sample, which is higher than studies using the previous waves of the CHNS data [Ren et al., 2019, p. 1759]. Nearly half of the participants considered in our sample are overweight, and 15.3 % of them are obese. According to the National Bureau of Statistics of China, China's rural population was nearly 603.45 million in 2015, and the overweight and obese populations calculated using this method were nearly 295.69 million and 33.54 million, respectively. Nevertheless, 2.8 % of individuals are observed to be underweight in our sample. Additionally, we also find a significant difference in BMIs between the male and female samples; the mean male BMI is 0.276 higher than the female. No significant differences are found for overweight and obesity, while it is revealed that females are more likely to be underweight.

Independent variables. Income inequality is the main independent variable of interest in this study. Generally, income inequality is used to show how unevenly income is distributed throughout a given population. The less equal the distribution, the higher income inequality is. There are plenty of methods for measuring income inequality [Li, Zhu, 2006, p. 676]. Following previous studies, we selected three widely used methods to measure the income inequality in our sample: the ranking of individual incomes in the community, the Yitzhaki index and the Kakwani index. First, the ranking of individual incomes is a good reflection of the income inequality in a community. In this study, since the database only includes total household income and the number of household members, we use the per capita household income to represent individual income. Specifically, samples from the same community are ranked in descending order by household income per capita (household income is adjusted according to Organisation for Economic Cooperation and Development (OECD) criteria). That is, the sample with rank = 1 has the highest per capita household income at the community level. A higher ranking indicates higher income inequality for a household within the community. Second, the Yitzhaki index was introduced by Yitzhaki in 1979 and has been used by many researchers to study income inequality [Li, Zhu, 2006, p. 677]. The Yitzhaki index provides a more accurate picture of income differences among individual community members than ranking. The specific formula for the Yitzhaki index is shown in the equation:

$$Yitzhaki_k = \frac{1}{n}\sum_{i=1}^{k-1}(income_i - income_k), \quad (4)$$

where $Yitzhaki_k$ is the Yitzhaki index of the *Kth* individual; $income_k$ is the annual per capita household income of the *Kth* farm household; $income_i$ denotes the per capita income of households in the same community as farmer *K* and whose annual household income is greater than *K*; *n* is the total number of people in the community. Note that since we calculate the Yitzhaki index using the per capita household income, it is the same for all the persons in the same household.

The third measurement is the Kakwani index, which was developed from the Yitzhaki index by Kakwani [Li, Zhu, 2006, p. 676]. In fact, the Kakwani index is the ratio of the individual Yitzhaki index divided by the average of the Yitzhaki index of all the people in the community μ_K. In contrast to the Yitzhaki index, the Kakwani index is no longer sensitive to population size. The specific formula for the Kakwani index is shown in the equation:

$$Kakwani_k = \frac{1}{n\mu_K}\sum_{i=1}^{k-1}(income_i - income_k), \quad (5)$$

where $Kakwani_k$ is the Kakwani index of farmer *K*; *i*, *n*, $income_i$ and $income_k$ are the same as in the equation (4); μ_K denotes the average Yitzhaki index of the community members of the farmer *K*. The Kakwani index differs from the Yitzhaki index in that it considers the effect of population size on the income inequality index.

Control variables. The main control variables in this study consisted of two components: individual demographic variables and family characteristics. Individual demographic variables included age, gender, education, marital status, whether the participants worked and their physical activities. Household characteristics mainly consisted of income and household size. As shown in Table 1, the average age of the participants in our sample is 47 years old, and nearly half of them are males; the average length of time spent in education is approximately 9.9 years; and more than 87.5 % and 56.3 % of them are married and are currently working, respectively. It also shows how 18.2 % of our sample perform heavy physical activities. Regarding the household controls, it is observed that the per capita household income is almost 30,000 CNY[1]; the average household size is 4.8 individuals.

Research results

The effect of income inequality on BMI. The main results regarding the BMI estimations are presented in Table 2. Columns 1, 2 and 3 in Table 2 represent the results of the effect of the three variables (Rank, Yitzhaki index and Kakwani index) on BMI, respectively. In general, the estimates of the three indices are largely consistent, showing a positive and significant effect of income inequality on BMI. This suggests that increasing income inequality is associated with higher BMIs for rural residents. Specifically, keeping the other variables unchanged, a one-rank increase in an individual's income ranking within

[1] 1CNY ≈ 0.16 USD in 2015.

the community leads to a 0.1 % increase in that person's BMI. The coefficients of both the Yitzhaki and Kakwani indices are also positive, which indicates that an increase in income inequality significantly increases individual BMIs.

Table 2. **The effect of income inequality on BMI of Chinese farmers**

Variables	Dependent variable: BMI		
	(1)	(2)	(3)
Rank	0.001* (0.00)	–	–
Yitzhaki index	–	0.001* (0.00)	–
Kakwani index	–	–	0.011* (0.01)
Age	0.009*** (0.00)	0.009*** (0.00)	0.009*** (0.00)
Age squared	–0.000*** (0.00)	–0.000*** (0.00)	–0.000*** (0.00)
Gender	0.015*** (0.00)	0.015*** (0.00)	0.015*** (0.00)
Education	–0.001** (0.00)	–0.001* (0.00)	–0.001* (0.00)
Marital status	–0.005 (0.01)	–0.005 (0.01)	–0.005 (0.01)
Occupation	0.004 (0.00)	0.004 (0.00)	0.004 (0.00)
Physical activities	–0.023*** (0.01)	–0.023*** (0.01)	–0.023*** (0.01)
LnIncome	–0.011 (0.01)	–0.009 (0.01)	–0.009 (0.01)
LnIncome squared	0.001 (0.00)	0.001 (0.00)	0.001 (0.00)
Household size	0.001 (0.00)	0.001 (0.00)	0.001 (0.00)
Constant	3.031*** (0.07)	3.037*** (0.07)	3.018*** (0.07)
Province controls	Yes	Yes	Yes
Number of observations	6,379	6,379	6,379

Note: *, ** and *** denote the statistical significance at the 10 %, 5 % and 1 % levels, respectively, and the numbers in brackets are standard errors. The results are cluster-corrected at the community level.

Source: own estimations using the CHNS data (2015).

It should be noted that the research of Ren et al. [2019, p. 1760] believes that there is an inverted U-shaped relationship between the income of rural residents and their BMIs, with the critical point of the quadratic curve of BMI and income positioned at around 26,627 CNY, and before 2011, low-income farmers in China were unlikely to

be overweight. However, our findings show that, in rural China in 2015, low-income groups are often likely to have a higher BMI and that there is a significant positive correlation between the individual income inequality index and nutrition outcomes.

Regarding the control variables, the results show a non-linear relationship between age and BMI, which is consistent with our expectation that middle-aged people are more likely to have a higher risk of obesity. The inflection point of age appears around the age of 44; that is, before 44, BMI will increase with age, but after 44, BMI will gradually decrease with any further increase in age. Our results also show that the males' BMI is significantly higher than that of females, which may be the result of Chinese women being more concerned about their weight **[Ren et al., 2021, p. 14]**. Similar to previous studies **[Woo, Leung, Kwok, 2007, p. 1891]**, we also found that individuals' education levels and the intensity of the physical activities they perform are negatively correlated with BMI.

The effect of income inequality on underweight, overweight and obesity. In this section, we explain the results of the multinomial logistic model. Specifically, we further discuss the effect of income inequality on underweight, overweight and obesity using normal weight as a reference.

As shown in Table 3, the results of the multinomial logistic model are largely consistent with the results from the OLS regressions. The coefficients of the three indicators of individual income inequality are all significantly positive in the estimation of overweight and obesity, except the coefficient of the Yitzhaki index, which is shown to be positive but insignificant. This result generally suggests that an increase in individual income inequality can significantly increase the risk of being obese and overweight. Unlike overweight and obesity, our results indicate that income inequality among rural residents has no significant effect on underweight. This suggests that an economical reason might not be the determinant of being underweight and that there might be some other reasons, such as cultural ones.

Income inequality has a significant effect on overweight and obesity, but not on underweight. This may be the result of the changing food intake of Chinese farmers as their incomes continue to rise. In present-day rural China, calorie deficiency is no longer the main problem facing Chinese farmers. The main nutrition-related problem encountered by Chinese farmers has shifted away from the demand for more food to the demand for higher quality food. The diversity of food consumption and how to achieve a balanced intake of nutrients are also new problems for most Chinese farmers.

We would like to emphasise that, from the perspective of nutritional outcomes, the effect of income inequality on Chinese farmers is likely to be concentrated in relatively low-income groups. That is to say, if the income inequality of Chinese farmers increases further, it will lead to a higher risk of overweight and obesity for people with lower incomes. On the one hand, for rural low-income groups, although they are able to meet their basic food and nutritional needs, their diet may not be balanced. For example, a high carbohydrate intake may be one factor that increases the risk of obesity among

Table 3. **The effect of income inequality on underweight, overweight and obesity among Chinese farmers**

Variables	Underweight			Overweight			Obesity		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Rank	0.004 (0.01)	–	–	0.004 (0.00)	–	–	0.009* (0.01)	–	–
Yitzhaki index	–	-0.004 (0.01)	–	–	0.006* (0.00)	–	–	0.013** (0.01)	–
Kakwani index	–	–	–0.208 (0.25)	–	–	0.059 (0.09)	–	–	0.209* (0.11)
Age	–0.186*** (0.05)	–0.187*** (0.05)	–0.187*** (0.05)	0.119*** (0.02)	0.120*** (0.02)	0.119*** (0.02)	0.067*** (0.02)	0.069*** (0.02)	0.067*** (0.02)
Age squared	0.002*** (0.00)	0.002*** (0.00)	0.002*** (0.00)	–0.001*** 0.00	–0.001*** 0.00	–0.001*** 0.00	–0.001*** 0.00	–0.001*** 0.00	–0.001*** 0.00
Gender	–0.27 (0.19)	–0.271 (0.19)	–0.274 (0.19)	0.125* (0.07)	0.129* (0.07)	0.125* (0.07)	0.131 (0.09)	0.139 (0.09)	0.133 (0.09)
Education	0.024 (0.02)	0.025 (0.02)	0.027 (0.02)	–0.009 (0.01)	–0.009 (0.01)	–0.008 (0.01)	–0.009 (0.01)	–0.009 (0.01)	–0.009 (0.01)
Marital status	0.065 (0.26)	0.066 (0.26)	0.061 (0.26)	0.180* (0.10)	0.178* (0.10)	0.179* (0.10)	–0.033 (0.15)	–0.039 (0.15)	–0.035 (0.15)
Occupation	–0.025 (0.20)	–0.026 (0.20)	–0.026 (0.20)	0.006 (0.07)	0.007 (0.07)	0.008 (0.07)	–0.02 (0.09)	–0.018 (0.09)	–0.017 (0.09)
Physical activities	0.259 (0.25)	0.254 (0.25)	0.254 (0.25)	–0.087 (0.09)	–0.086 (0.09)	–0.086 (0.09)	–0.224** (0.11)	–0.222** (0.11)	–0.220** (0.11)
LnIncome	1.12 (0.79)	1.213 (0.78)	1.265 (0.77)	0.015 (0.19)	0.016 (0.19)	0.039 (0.19)	–0.049 (0.27)	–0.044 (0.28)	–0.019 (0.28)
LnIncome squared	–0.063 (0.05)	–0.071 (0.04)	–0.078* (0.05)	0.001 (0.01)	0.001 (0.01)	0.000 (0.01)	0.009 (0.02)	0.007 (0.02)	0.008 (0.02)
Household size	0.065 (0.05)	0.065 (0.05)	0.064 (0.05)	–0.007 (0.02)	–0.005 (0.02)	–0.006 (0.02)	0.026 (0.03)	0.029 (0.03)	0.03 (0.03)
Constant	–4.782 (3.66)	–4.775 (3.70)	–4.374 (3.66)	–3.224*** (1.00)	–3.197*** (0.97)	–3.269*** (1.00)	–2.491* (1.41)	0.013** (0.01)	–2.757* (1.46)
Province controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	6,379	6,379	6,379	6,379	6,379	6,379	6,379	6,379	6,379

Note: *, ** and *** denote the statistical significance at the 10 %, 5 % and 1 % levels, respectively, and the numbers in brackets are standard errors. The results are cluster-corrected at the community level.

Source: own estimations using the CHNS data (2015).

Chinese farmers [Burggraf et al., 2015, p. 1009]. On the other hand, low-income farmers tend to face greater social and economic pressure, which will not only directly harm the psychological health of farmers and increase their risk of obesity [Shimokawa, 2013, p. 44], but may also make them invest more energy and time in agricultural production activities, which could destroy the normal diet of farmers. This puts low-income farmers at a higher risk of being overweight and obese.

Robustness check. To further check the robustness of our results, a binary outcome was defined and estimated using a probit model, as discussed in the earlier section. The estimation results of the probit model are shown in Table 4. The main results are largely consistent with those from the OLS and multilogit estimations. Thus, we can conclude that income inequality can significantly increase the unhealthy nutritional outcomes of being overweight and obese.

Table 4. **The estimates of the robustness test**

Variables	Overweight			Obesity		
	(1)	(2)	(3)	(4)	(5)	(6)
Rank	0.003 (0.00)	–	–	0.004* (0.00)	–	–
Yitzhaki index	–	0.005** (0.00)	–	–	0.006** (0.00)	–
Kakwani index	–	–	0.070 (0.05)	–	–	0.099* (0.06)
Other variables	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	6,379	6,379	6,379	6,379	6,379	6,379

Note: *, ** and *** denote the statistical significance at the 10 %, 5 % and 1 % levels, respectively, and the numbers in brackets are standard errors. The results are cluster-corrected at the community level.

Source: own estimations using the CHNS data (2015).

Heterogeneity analysis. As mentioned above, significant differences exist in nutritional outcomes between males and females in rural China. Thus, it is necessary to examine if there are gender-specific effects of income inequality on nutritional outcomes. In this section, we will discuss the heterogenous effect of income inequality on the nutritional outcomes for the male and female samples using OLS and multinomial logistic estimations.

As shown in Table 5, for the male sample, increasing income inequality significantly increases its BMI, while it has no significant effect on the change in the BMI of the females. The multinomial logistic model regression results also showed that income inequality significantly increases the risk of overweight for males, but has no significant effect on the equivalent for females. In the model of the effect of income inequality on obesity, it is noteworthy that the Y-index is significant for both men and women, suggesting that income inequality may have an effect on obesity in both. However, we also need to note that the coefficient of the female sample (0.001) is much lower than (and, in fact,

Table 5. **The estimations of the heterogeneity analysis**

Variables	BMI			Underweight			Overweight			Obesity		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Male sample												
Rank	0.023** (2.55)	–	–	–0.002 (0.01)	–	–	0.008 (0.00)	–	–	0.014** (0.01)	–	–
Yitzhaki index	–	0.001*** (2.72)	–	–	0.003 (0.01)	–	–	0.013*** (0.00)	–	–	0.016** (0.01)	–
Kakwani index	–	–	0.022*** (2.73)	–	–	–0.118 (0.33)	–	–	0.152** (0.08)	–	–	0.352** (0.15)
Other variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	3,052	3,052	3,052	3,052	3,052	3,052	3,052	3,052	3,052	3,052	3,052	3,052
Female sample												
Rank	0.004 (0.01)	–	–	0.009 (0.01)	–	–	0.000 (0.00)	–	–	0.006 (0.01)	–	–
Yitzhaki index	–	–0.000 (0.00)	–	–	–0.008 (0.01)	–	–	0.001 (0.00)	–	–	0.001** (0.01)	–
Kakwani index	–	–	0.001 (0.01)	–	–	–0.304 (0.32)	–	–	–0.029 (0.11)	–	–	0.096 (0.13)
Other variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	3,327	3,327	3,327	3,327	3,327	3,327	3,327	3,327	3,327	3,327	3,327	3,327

Note: *, ** and *** denote the statistical significance at the 10 %, 5 % and 1 % levels, respectively, and the numbers in brackets are standard errors. The results are cluster-corrected at the community level.

Source: own estimations using the CHNS data (2015). Note that: a. BMI is estimated by OLS estimation; b. underweight, overweight and obesity are estimated by multinomial logistic estimation.

only 1/16) that of the male sample (0.016). This suggests that the worsening of income inequality in rural China mainly significantly increases the risk of obesity in males, while the effect on obesity in females is very small.

Results and discussion

Since the reform and opening up of the country, the per capita income of Chinese farmers has increased rapidly, and their living environments and nutritional intake have changed significantly. These changes have switched the nutritional problem faced by Chinese farmers from a calorie deficit to an excess of calories. Based on the latest data from the CHNS in 2015, we explored the effect of income inequality on nutritional outcomes, including BMI, underweight, overweight and obesity statuses. A set of measurements for income inequality are considered. Some studies have shown that high-income groups in China have a higher risk of obesity, but our results show that low-income groups have a higher risk of obesity. Moreover, the current increase in income inequality in rural China may further increase the risk of overweight and obesity among farmers with relatively low incomes. The findings are consistent when various model specifications are applied.

There are two ways to understand why increasing income inequality in China today primarily increases the risk of obesity in low-income groups. The first possible reason is that income inequality may have a positive effect on BMI by compromising individual food and nutritional intake. For instance, it is found that, unlike in China in the 1980s, when the country had just implemented reform and opening-up policy, most Chinese people are no longer suffering from hunger **[Yuan et al., 2017, p. 3]**. Therefore, food diversity and whether it is of a high quality may have a greater effect on nutritional outcomes than larger quantities of food **[Ren, Li, Wang, 2019, p. 58]**. It is argued that low-income groups tend to be more likely to have unhealthy food consumption habits, and their consumption in terms of food diversity is usually worse due to budget constraints that have a negative effect on their nutritional intake of food **[Li, Lopez, 2016, p. 4526; Yuan et al., 2017, p. 5]**. However, after a certain income level, further increases in income have little effect on individual nutritional intake. This means that further increases in the income of high-income farmers may not have a positive effect on their nutritional outcomes. Therefore, income inequality may positively effect nutritional outcomes by undermining food diversity and dietary preferences, mainly among low-income groups.

The second possible reason is that income inequality may also negatively affect BMI in low-income groups by undermining their social relationships, general trust and self-confidence. In general, people in areas with higher levels of income inequality tend to be more likely to agree that most people cannot be trusted, and they have poorer social relationships and more negative psychological states **[Sekabira, Qaim, 2017, p. 98]**. In addition, these negative psychological factors may contribute to irregular eating habits and are detrimental to the spread and dissemination of nutritional knowledge. Based on the fact that most people in China no longer suffer from hunger, the relative income

of households has a greater effect on individual nutritional outcomes than absolute income at the community level from an individual psychological perspective. The negative effect of income inequality on nutrition and health in China is more pronounced in low-income groups as they typically face more strained social relationships and low self-confidence.

Interestingly, the heterogeneity results of this study suggest that income inequality primarily affects nutritional outcomes in males. Since the vast majority of income in rural Chinese households comes from male members and women are usually more concerned with their weight, it is likely that income inequality has no effect on women's risk of overweight. The reason for the heterogeneity between male and female samples may come from two sources. On the one hand, in rural China, the main income of most families comes from men, and men often face more economic pressure than women. Therefore, the effect of income inequality on men may be greater than that on women. Besides, a more important reason may be that Chinese women with both high and low incomes pay a lot of attention to their weight, and they often try to control it in various ways, such as through dieting, exercising or even taking diet pills. These artificial interventions counteract the effect of income inequality on the risk of obesity, and thus income inequality will increase the risk of obesity mainly in the male population.

Conclusion

In the context of the negative effect of income inequality on farmers' nutritional outcomes in China, the findings of this study have several important policy implications. First, we suggest that the Chinese government should pay more attention to income inequality while working to improve the incomes of Chinese farmers. Second, because China has few policies to improve nutrition in rural areas, the government should learn from the experience of developed countries and implement some nutrition programmes in such areas to improve the nutritional status of Chinese farmers. Third, men and low-income groups in rural areas of China may face more serious nutritional problems; therefore, China's rural nutrition policies should give more consideration to men and low-income groups.

Overall, this study also has some shortcomings. First, although our research sample is representative, it only contains survey data from 2015, so it would be better if researchers could use panel data from more recent years. Another limitation of this study is that we only focus on one dimension of income inequality, namely inequality at the community level. Further research could focus on income inequality in communities as well as at the township and county levels.

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