Urbanicity and nutrition: evidence from rural–urban migrants in China

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Abstract

Purpose – The purpose of this paper is to examine the impact of urbanicity on rural–urban migrants' dietary diversity and nutrition intake and whether its effect differs across various urban environments of migrants.

Design/methodology/approach – Using the individual- and time-invariant fixed effects (two-way FE) model and five-year panel data from the China Health and Nutrition Survey (CHNS), this paper estimates a linear and nonlinear relationship between urbanicity and nutrition. The paper also explores the spatial heterogeneity between rural–urban migrants and rural–suburban migrants. Dietary diversity, total energy intake and the shares of energy obtained from protein and fat, respectively, are used to measure rural–urban migrants' nutrition on both quality and quantity aspects.

Findings – The study shows that rural–urban migrants have experienced access to more diverse, convenient and prepared foods, and the food variety consumed is positively associated with community urbanicity. Energy intake is positively and significantly affected by community urbanicity, and it also varies with per capita household income. The obvious inverse *U*-shaped relationship reveals that improving community urbanicity promotes an increase in the shares of energy obtained from protein and fat at a decreasing rate, until reaching the urbanicity index threshold of 66.69 and 54.26, respectively.

Originality/value – This paper focuses on the nutritional status of rural–urban migrants, an important pillar for China's development, which is often neglected in the research. It examines the urbanicity and

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the nutrition of migrants in China, which provides a new perspective to understand the dietary and nutritional intake among migrants in the economic and social development. Moreover, the urbanicity index performs better at measuring urban feathers rather than the traditional rural/urban dichotomous classification.

Keywords Urbanization, Rural–urban migrants, Food diversity, Nutrition, China

Paper type Research paper

1. Introduction

Urbanicity entails the characteristics of urban environments or the degree to which a place portrays the urban characteristics, while urbanization is often used to denote the change in size, density and heterogeneity of cities (Vlahov and Galea, 2002; Montgomery *et al.*, 2003). Rapid urbanization in developing countries induced by foreign direct investment, industrialization and changes in economic structure is shaping food security and nutrition (Cockx *et al.*, 2018). However, the existing research on nutrition and food security tends to focus mainly on rural areas. Urban population growth and area expansion, as well as environmental degradation and climate change, induce increasing pressure on agricultural production and the global food system (Fan, 2017). Furthermore, as urbanization accelerates in developing countries, the triple burdens of hunger, undernutrition (inadequate intake of macro- and micronutrients) and overnourishment (in the form of overweight and obesity malnutrition) coexist and worsen (IFPRI, 2016). Although the aforementioned issues have attracted global attention, and researchers as well as policymakers have engaged in reducing food insecurity and undernutrition in rural areas, there is a long way to go in order to achieve the dual goals of food security and nutrition (Bloem and de Pee, 2017; Crush and Frayne, 2010; Mohiddin *et al.*, 2012). Malnutrition in urban areas, including the prevalence of obesity, is higher and rising more rapidly than in rural areas, which needs more attention and inclusion in urban-focused work (Ruel *et al.*, 2017).

Diets are changing with rising incomes and urbanization, and the latter seems to play an increasingly critical role in dietary patterns (Mendez and Popkin, 2004; Schmidhuber and Shetty, 2005; Cockx *et al.*, 2019a, b; d'Amour *et al.*, 2020). Urbanization is associated with a change in diets from traditional fresh foods to more preprepared and processed foods with higher sugar and fat (Dixon *et al.*, 2007; Tzioumis and Adair, 2014; Wu *et al.*, 2017). Furthermore, processed foods are cheaper and more convenient than most nutritious fresh foods such as vegetables and animal-sourced foods that need to be further prepared. Obviously, diverse and convenient food access and more sedentary lifestyles in urban areas are more likely to lead to obesity and other nutrition-related noncommunicable diseases (Cockx *et al.*, 2018). Although changes in diet patterns are considered one of the driving forces behind the nutrition transition, there is a limited understanding of whether and how the nutrition transition is linked to urbanization.

China has experienced rapid urbanization and economic growth since 1978, which promoted a socioeconomic transformation in China. In 2011, the number of people living in urban areas exceeded those residing in rural ones for the first time. Urbanization rate for China in 2018, calculated as the proportion of the urban population to the total population, increased from 17.92% in 1978 to 59.58% (NBSC, 2018). This growth of urban population is the result of natural urban population growth, reclassification of rural areas into urban and rural–urban migrants, which respectively affect the urbanization rate by 0.42, 0.25 and 0.39 percentage points compared to 2017 (Li, 2019). With accelerated urbanization, more and more rural residents will migrate to urban centers or towns in the future, putting pressure on the urban food system. Their dietary patterns and nutrition will gradually change with the evolution of income, food supply environments, food preferences and eating habits, lifestyle, nutrition knowledge and other conditions (Cockx *et al.*, 2018).

A great deal of literature investigates the relationship between urbanization and food consumption and nutrition. At the cross-country level, Huang and David (1993) estimate a two-stage demand system model on aggregate time-series data for Asia and found that urbanization decreases the consumption of coarse grains and raises the consumption of wheat and animal-sourced foods. Popkin (1999) uses cross-country comparisons, along with the limited longitudinal analysis and found that urbanization is positively related to the consumption of sweeteners and fats. Huang (1999) points out that urbanization in China plays a decisive role in food consumption structure change, which continues to affect future food consumption. Another study demonstrates that urbanization in China increases the demand for meats, fruit and eggs while reducing demand for grains, vegetables and fats and oils (Hovhannisyan and Devadoss, 2020). Some researchers believe that urbanization improves nutrition by increasing nonagricultural income and reducing the market distance to access nutritious food (Zhai *et al.*, 2017; Li *et al.*, 2018); obtaining knowledge and information on nutrition (Cheng and Yang, 2015); and accessing more modern medical resources and convenient infrastructures (Zhang, 2012). However, urbanization increases the consumption of high-sugar, high-fat and high-processed foods associated with a sedentary lifestyle, thus promoting obesity and increasing the chances of people being overweight (Cockx *et al.*, 2018; Zhao and Zheng, 2016; Zeng and Zeng, 2018). In addition, urbanization increases the number of urban residents, leading to a shortage of medical resources and higher medical costs, which is not conducive to nutrition and health (Wu and Li, 2014).

The current and dominant understanding of urbanization and food consumption and nutrition is usually predicated on the urban–rural dichotomy or the proportion of the urban population. However, urbanization involves changes at multiple levels, including population and population density, infrastructure, economic activity, markets and so on. Although previous studies help us understand the existing differences in food consumption and nutrition between rural and urban residents, it is still challenging to capture the multiple dimensions of urbanization on food consumption and nutrition. In addition, the traditional classification of urban/rural likely does not allow us to explore how living in different urban environments affects dietary patterns and nutrition. Therefore, there is a need to employ an improvement measurement of urban environments when analyzing its effect on food consumption and nutrition. Urbanicity outperforms the urban/rural dichotomy to quantify the urban environment or features (Vlahov and Galea, 2002; Dahly and Adair, 2007; Jones-Smith and Popkin, 2010). A recent study indicates that adults living in the highest urbanicity have more dietary fat intake, and a greater proportion of energy from total fat, compared to the lowest urbanicity (Su *et al.*, 2020).

Most of the existing literature focuses on the food consumption and nutrition of rural or urban populations and less on the rural–urban migrants, an important group in the process of urbanization in China. In particular, due to the restrictions of the household registration system (hukou) in China, rural–urban migrants do not receive the same education, healthcare, social security and other public services as registered urban residents do. This may cause adverse nutritional outcomes, as migrant households need to allocate a greater proportion of their budget to those services. In the context of rapid urbanization, it is expected that large numbers of rural residents will continue to move to urban areas in China. Against the backdrop of rapid urbanization and rural–urban migration, changes in dietary diversity and nutrition of rural–urban migrants and its link with urbanicity of the places to which they relocate warrant in-depth research. Better understanding of the relationship between urbanicity and migrants' food and nutrition could help improve ongoing reform to build a healthy China, which includes the registration system, education, employment, medical care, affordable housing and public social services.

In the present paper, we use five longitudinal data from the China Health and Nutrition Survey (CHNS) from 2000 to 2011 to examine the effects of urbanicity on dietary diversity and nutrition intake for adult rural–urban migrants and explore whether its effects differ for those who have migrated to urban and suburban areas. This article makes three contributions to the literature. First, we pay close attention to rural–urban migrants, who are disadvantaged groups living in urban areas. This growing special group has been less researched or even neglected in current literature. Second, improved measurement of urbanicity is utilized to quantify the urban environment, allowing us a better understanding of the relationship between urbanicity and nutrition, compared to traditional rural/urban dichotomy. Finally, we select indicators from nutritional quantity (i.e. total energy intake) and quality (i.e. dietary diversity, the share of energy from protein and fat), which can better measure individuals' nutritional status. In addition to modeling the linear relationship, we also investigate the nonlinear relationship between urbanicity and nutrition presenting interesting findings.

The rest of the paper is organized as follows. In the second section, we construct the theoretical framework of nutrition, while Section 3 introduces the econometric models. Data and basic descriptive statistics are presented in Section 4, and Section 5 shows the empirical results while Section 6 discusses the marginal effects of urbanicity and nutrition. The last section concludes with policy implications.

2. Theoretical framework

The general theoretical framework for modeling food and nutrition intake is well established as an application of the Lancaster household production function (Park and Davis, 2001; Ramezani, 1995). Many factors across individual, household and community levels affect food and nutrition intake, but the key one of interest here is community urbanicity (U). Consequently, a function of nutrition intake (NI) is set as follows:

$$\mathrm{NI} = f(U, I, Z) \tag{1}$$

where I is the income, and Z is a vector of other socioeconomic characteristics (e.g. age, education, household size, etc.) that would be expected to affect nutrition intake.

Urbanicity is both the consequence of and complementary to urbanization (Vlahov and Galea, 2002), which intrinsically reflects the quality of urbanization development. Evidently, urbanicity affects food consumption and nutrition intake from various aspects of community features (see Figure 1). Well-urbanized areas, which are generally characterized by good access to food markets and transportation infrastructure, may positively affect food diversity and nutrition intake of individuals. Communities with high quality of urbanization reduce the costs of accessing nutrient-rich and diverse foods through reducing the distance to different markets (convenience stores, supermarkets and hypermarkets, etc.), thus the households or individuals in proximity to the market have more diverse diets than those in remote areas (Stifel and Minten, 2017; Headey *et al.*, 2019). Moreover, regions with higher urbanicity have more developed communication equipment and information technology, thereby increasing nutrition knowledge and prompting nutritional intake. It is, therefore, not surprising that urbanicity promotes nutrition improvement from the aforementioned pathways.

However, urbanicity may have a negative effect on food consumption and nutrition. Specifically, highly urbanized regions are generally characterized by more energy-intensive and high-processed food consumption and lower physical activity levels, resulting in excessive energy intake and malnutrition. Households or individuals living near restaurants or supermarkets tend to eat out more frequently and purchase more processed or fast foods with high-sugar or fat contents (Nickanor *et al.*, 2017). In addition, residents living in highly developed areas (some megacities), especially rural–urban migrants, need to pay more nonfood expenditures such as housing, medical facilities and social public services without the protection and benefits afforded by hukou registration, thereby cutting off household food expenditures (Darrouzet-Nardi and Masters, 2015). This may induce a decline in dietary

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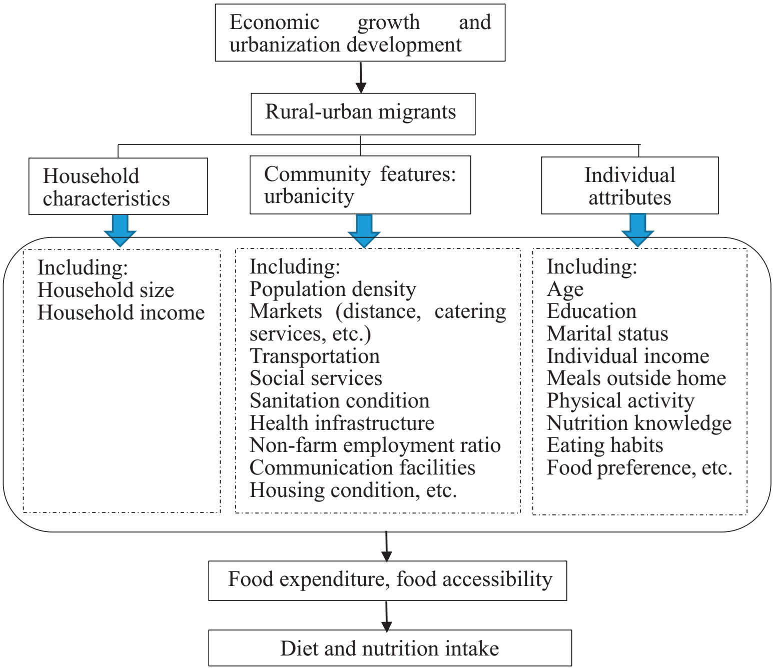


Note(s): The line arrows indicate causality; the blue arrows indicate specific contents

Figure 1.
Theoretical framework

diversity and nutritious food with high protein. Overall, it is assumed that urbanicity has a positive effect on food diversity and nutrition intake to a certain extent. Taking this into account, we investigate the linear and nonlinear relationship between community urbanicity and diet and nutrition intake for migrants.

Income is recognized as the most critical internal attribute for food consumption and nutrition since a significant share of household budgets is allocated to food. Income is assumed to produce two nutritional outcomes. As income increases, both urban and rural residents tend to consume more fruit, dairy products and animal-based food (pork, beef, poultry, duck, etc.) and less cereals (Streeter, 2017), indicating that income growth can eliminate undernutrition and improve nutritional status (Salois *et al.*, 2012; Ogundari and Abdulai, 2013). However, income growth also promotes high-calorie, high-fat and low-nutrient processed food consumption (Ridoutt *et al.*, 2016), thus increasing the risk of diet-related noncommunicable diseases such as obesity (Prentice, 2006). According to the Engel curve, energy intake increases with income at a certain level but does not increase without limit (Zhou and Yu, 2015). Therefore, the marginal effects of income on nutrition are expected to be focused on in the future.

Nonagricultural employment in urban areas is associated with higher income (Scharf and Rahut, 2008, 2014) and lower energy requirements (Deaton and Drèze, 2009). More labor market opportunities for females and longer commuting distances in urban areas raise the opportunity costs of time to acquire and prepare food, leading to greater preferences for processed and fast food and an increase in the frequency of dining out. Dining out is common among urban households and families with female members in the nonfarm sector

(Mottaleb *et al.*, 2017), which may increase food diversity and energy intake. Influenced by urban residents' lifestyles associated with an increase in nutrition and health awareness from modern mass media, migrants may gradually change their lifestyles and engage in more physical exercise, which helps improve diet and nutrition. Younger and married people may consume more food and nutrient. Other socioeconomic characteristics such as education level, physical activity and household size are expected to positively affect food and nutrition intake.

3. Methods

3.1 Measurement of nutrition

Food consumption modules of the CHNS have been used to analyze various aspects of dietary change and nutrition intake in China, including the effect of food variety accessibility on dietary diversity (Liu *et al.*, 2014), nutrition improvement and dietary change using different indices (Tian and Yu, 2015), food away from home consumption and energy intake (Zeng and Zeng, 2018) and food accessibility, agricultural production diversity and dietary patterns (Huang and Tian, 2019). In this study, we employ four indicators in terms of the quantity and quality of nutrition to better understand nutritional status. The four indicators are dietary diversity score (DDS), total energy intake, the share of energy obtained from protein and the share of energy obtained from fat. The total energy intake reflects the quantity of nutrition, and the other three quality indices capture changes in diet and the structure of energy.

Specifically, DDS is obtained by identifying the number of different food groups or items consumed in a specific period, which includes the accessibility to food varieties and is correlated with energy sufficiency (Pérez-Escamilla *et al.*, 2017). In this paper, we count the number of different food items consumed daily (see Appendix Table A1). We then add up the daily DDS for each person to get total scores for the three survey days. Finally, we obtained the average number of food items that are not repeatedly consumed within one day and used it to measure individual dietary diversity. The calculation is as follows:

$$\mathrm{DDS}_i = \frac{1}{3}\sum_{d=1}^{3}\sum_{j=1}^{n} fc_{idj} \tag{2}$$

where fc_{idj} indicates whether the individual i consumes the jth food item on the dth survey day. If consumed, it is recorded as 1, otherwise, it is 0. It is worth mentioning that edible oils and condiments consumed by individuals were not counted, which is consistent with the 2016 Chinese Dietary Guidelines.

The daily energy intake per capita is converted from food consumption based on the Chinese Food Composition Table (FCT) and can be obtained directly from the CHNS. Notably the decrease in total energy intake does not necessarily mean that rural–urban migrants' nutritional status has worsened. If individuals increase the consumption of better quality, but fewer energy alternative foods, the energy intake structure may improve even if the quantity of energy intake decreases (Tian and Yu, 2015). Hence, it is necessary to incorporate the source of energy to measure nutritional quality, which is particularly important for an accurate assessment of nutrition improvement.

In terms of nutritional quality, we further assess the share of energy from protein and fat, respectively. According to the Chinese FCT, 1 g of protein can provide 4 kcal of energy, and 1 g of fat can provide 9 kcal of energy. The conversion formulas are as follows:

$$\mathrm{Yprotn} = \frac{\mathrm{protein} * 4}{\mathrm{energy}} \tag{3}$$

$$\mathrm{Yfat} = \frac{\mathrm{fat} * 9}{\mathrm{energy}} \tag{4}$$

Here, the Yprotn and Yfat are separately defined as the share of energy intake from protein and fat. The individual daily energy, protein and fat intake is acquired from the CHNS. To sum up, four dependent variables are used to measure dietary diversity and nutrition, respectively.

3.2 Measurement of urbanicity

The key explanatory variable of interest is the community urbanicity, an effective indicator for quantifying the urban environments or features (Dahly and Adair, 2007; Jones-Smith and Popkin, 2010). At the community level, the CHNS has collected relevant data such as population density, social services availability, markets, infrastructure and so on. Following Jones-Smith and Popkin (2010), this article relies on the urbanicity index of community, which is identified by 12 components. These components are the population density, economic activity, traditional markets, modern markets, transportation infrastructure, sanitation, communication, housing, education, diversity, health infrastructure and social services (for a detailed discussion, see Jones-Smith and Popkin (2010)). A maximum score of 10 was allotted to each component, and the scoring algorithms were developed based on distributions in the data. The total scale scores reported as one-dimensional index ranges from 0 to 120 with lower values indicating a lower level of community urbanization development. The index has been demonstrated to be valid and reliable and has been widely utilized (Van de Poel *et al.*, 2012; Attard *et al.*, 2015; Wu *et al.*, 2017). This improved measurement of urbanicity allows us to evaluate the changes in urban features and analyze differences in nutrition intake across different types of urbanized communities.

3.3 Empirical models

As demonstrated in the theoretical framework, nutritional intake depends on the urbanicity index, income and other socioeconomics factors. We initially specify the following estimation equation:

$$\mathrm{NI}_{ijt} = \alpha_0 + \alpha_1 \mathrm{index}_{jt} + \alpha_2 \ln h\mathrm{hinc}_{it} + \delta Z_{it} + \mu_{ijt} \tag{5}$$

where NI_{ijt} is the nutrition intake of individual i in the community j at year t, including (1) DDS, (2) total energy intake per capita per day, (3) the share of energy obtained from protein and (4) the share of energy obtained from fat. The index_{jt} indicates the urbanicity of community j at year t, and the $h\mathrm{hinc}_{it}$ is the household income per capita at year t. Z_{it} stands for the vector of control variables, including age, education, marital status, dining outside home, physical activity and household size. μ_{ijt} denotes the error term, including some unobserved variables such as eating habits, food preference and lifestyle.

Given the possible nonlinear nexus of urbanicity and nutrition, we incorporate the square term of urbanicity index into the model. The estimation model is as follows:

$$\mathrm{NI}_{ijt} = \beta_0 + \beta_1 \mathrm{index}_{jt} + \beta_2 \mathrm{index}_{jt}^2 + \beta_3 \ln h\mathrm{hinc}_{it} + \lambda Z_{it} + \mu_{ijt} \tag{6}$$

Generally, income as the major determinant of nutrition has been widely discussed in previous literature on income and energy intake. As Li *et al.* (2018) discussed, community urbanicity and individual income could have an interaction effect, it is highly likely that the impact of urbanicity on total energy intake for migrants varies across different income groups. Therefore, we estimate model (7) with the interaction term of urbanicity and income as follows:

$$\ln \text{energy}_{ijt} = \theta_0 + \theta_1 \ln \text{index}_{jt} + \theta_2 \ln h\text{hinc}_{it} + \theta_3 \ln \text{index}_{jt} * \ln h\text{hinc}_{it} + \gamma Z_{it} + \mu_{ijt} \quad (7)$$

Based on the panel data in this study, the models (5)–(7) can be estimated using both fixed-effects and random-effects regressions. The random-effects estimator assumes that explanatory variables are uncorrelated with any unobserved factors influencing diet and nutrition intake. However, this assumption may be violated because individuals self-select to consume nutritious foods, and unobserved factors such as lifestyle and eating habits may be influenced by the urbanicity of communities where they live, thus leading to a biased estimate. Employing a fixed-effects model controls for bias that may arise from unobserved time-invariant variables. A Hausman test can further verify the validation of the two estimators.

It is worth noting that our interest here is the urbanicity of communities in which migrants live. Generally, the community where people live is different from where they work. In view of this, we suppose that community urbanicity does not have a strong correlation with individual or household income. Given that the communities where migrants live show their self-selection behavior, we further introduce the propensity score matching (PSM) method to correct self-selection bias and test the robustness of the results.

4. Data and descriptive statistics

4.1 Data and sample

The rich data used in this study was extracted from five rounds of the CHNS, which is an ongoing open cohort, international collaborative project. A multistage, random cluster process is used to draw the samples from 12 provinces (three provinces, Shaanxi, Yunnan and Zhejiang, were joined since 2015), which differ in topography and socioeconomic status, including income, employment, education and modernization, as well as other related health indicators. Detailed information on communities, households and individual socioeconomic characteristics and dietary intake was collected for three consecutive days.

To derive our sample, we first classified individuals into four groups based on their household registration type (i.e. hukou: urban or rural) and residence (urban or rural) at the time of the CHNS interviews. Then we selected people with a rural hukou who were living in urban areas and defined them as rural–urban migrants. We further narrowed down our sample to adults aged 18 years and older. We obtained 4,469 observations with complete information after screening for the anomalous data. Of the total sample, 4,134 were rural–suburban and 335 were rural–urban.

4.2 Descriptive statistics

Summary statistics of variables used in the study are shown in Table 1. On average, each migrant consumes about seven types of food per day, and rural–urban migrants have more diverse diets than rural–suburban migrants (8.88 vs 6.83).

The total energy intake per capita per day is 2051.33 kcal. On average, it is higher for rural–suburban migrants than rural–urban migrants, which may be because the rural–suburban migrants are engaged in heavy work requiring more energy intake. As for the structure of energy, the average share of energy obtained from protein per capita per day is 12.55%, and that from fat per capita per day is 30.65%. The summary statistics also reveal that rural–urban migrants have a higher share of energy obtained from both protein and fat than rural–suburban migrants. It is worth noting that the share of energy provided by fat for rural–urban migrants (34.80%) exceeds the maximum of 30% recommended by the Chinese Dietary Guidelines. To sum up, there are differences in dietary diversity and nutrition between rural–urban and rural–suburban migrants.

Variables	Definition	Overall	Urban	Suburban
DDS	Number of food items consumed per capita per day	6.97 (2.36)	8.88 (2.75)	6.83 (2.27)
Energy	Total energy intake per capita per day (kcal/p/d)	2,051.33 (715.6)	1,983.20 (643.04)	2,056.39 (720.5)
Lnenergy	Logarithm of total energy intake per capita per day	7.565 (0.36)	7.539 (0.33)	7.567 (0.36)
Yprotn	Share of energy obtained from protein per capita per day (%)	12.55 (3.06)	13.60 (2.88)	12.47 (3.05)
Yfat	Share of energy obtained from fat per capita per day (%)	30.65 (12.43)	34.80 (12.00)	30.34 (12.41)
Index	Urbanicity index	63.10 (17.43)	89.52 (8.47)	61.14 (16.29)
Lnindex	Logarithm of urbanicity index	4.11 (0.28)	4.49 (0.10)	4.08 (0.27)
Lnhhinc	Logarithm of household income per capita at 2015 price	10.82 (0.32)	10.87 (0.16)	10.81 (0.33)
Age	Age in years	46.09 (15.41)	45.24 (16.45)	46.16 (15.33)
Married	1 = Yes, 0 = No	0.878 (0.33)	0.861 (0.35)	0.879 (0.33)
Hhsize	Number of household members	4.05 (1.47)	3.74 (1.20)	4.08 (1.49)
Fafh	Number of meals outside home per day	1.28 (2.00)	2.00 (2.35)	1.23 (1.96)
Educ	Highest education level			
Illiterate or primary school	1 = Yes, 0 = No	0.488 (0.49)	0.341 (0.47)	0.499 (0.50)
Middle school	1 = Yes, 0 = No	0.345 (0.48)	0.301 (0.46)	0.348 (0.48)
High or technical school	1 = Yes, 0 = No	0.148 (0.35)	0.266 (0.44)	0.139 (0.35)
University or higher	1 = Yes, 0 = No	0.019 (0.14)	0.092 (0.29)	0.014 (0.12)
Phyact	Physical activity level			
Light	1 = Yes, 0 = No	0.427 (0.49)	0.759 (0.43)	0.403 (0.49)
Moderate	1 = Yes, 0 = No	0.178 (0.38)	0.206 (0.40)	0.176 (0.38)
Heavy	1 = Yes, 0 = No	0.394 (0.49)	0.035 (0.18)	0.421 (0.49)

Note(s): Standard deviations are in parentheses

Table 1. Definition and descriptive statistics

We further compared the diet and nutrition intake for migrants with that for urban dwellers. The results in Appendix Table A2 show that dietary diversity and the structure or quality of energy intake (i.e. Yprotn and Yfat) for both migrants and urban dwellers have improved in 2011 from 2000, while the absolute intake of energy, fat and protein declined during the same period. The overall diet diversity and nutrition intake (except energy intake) for migrants are significantly lower than that for urban dwellers at 1% significance level.

The average community urbanicity index is 63.10 in Table 1, of which urban areas exhibit a higher degree of development than suburbs (89.52 vs 61.14). Table 1 also summarizes other control variables. Household income, on average, is higher for migrants living in urban areas and shows a weak correlation with community urbanicity (Appendix Table A3). The average age of the migrants is about 46 years, and 87.8% are married. The average migrant household size is more than 4 and is slightly higher for the migrants living in the suburb. On average, 1.28 meals are consumed per day outside the home, which is higher for those living in urban areas (2.00). Approximately 49.0% of respondents have an education level of primary and below (including illiterate), 34.5% have completed middle school, 14.8% have high school or technical-level schooling and 1.9% have a university-level education. The data also shows that migrants living in urban areas have higher education levels than those living in the suburbs. Approximately 42.7% do light physical activity and 39.4% do heavy physical activity. In particular, 75.9% of the migrants living in urban areas do light physical activity, which is 40.3% for migrants living in suburban areas. Only 3.5% of rural–urban migrants have heavy physical activity, while this proportion is 42.1% for those living in the suburbs.

4.3 Changes in diet and nutrition for migrants over time

Dietary diversity and nutrition for migrants vary significantly over time, as demonstrated by the nonparametric Kruskal–Wallis tests in Tables 2 and 3. Overall, dietary diversity has gradually increased by 30.54% from 6.09 in 2000 to 7.95 in 2011 (Table 2). The average daily energy intake has dramatically declined from 2,235.56 kcal in 2000 to 1,728.04 kcal in 2011, a 22.70% drop. Table 3 shows that the share of energy obtained from protein has increased

		DDS			Energy(kcal/p/d)	
Year	Overall	Urban	Suburban	Overall	Urban	Suburban
2000	6.09	6.40	6.08	2,235.56	2,131.60	2,238.65
2004	6.18	8.65	6.00	2,176.64	2,064.50	2,184.90
2006	7.00	9.66	6.78	2,135.03	1,980.61	2,147.92
2009	7.49	9.33	7.34	2,031.00	2,098.55	2,025.79
2011	7.95	8.85	7.85	1,728.04	1,822.10	1,717.90
RR[a]					1,600–2,400 kcal/d	
T-stat.[b] Ha:diff≠0		−13.65***			2.05**	
Z-stat.[c] H0:Murb = Msurb		−13.53***			1.81*	
Kruskal–Wallis $\chi^2(p)$[d]		501.21 (0.000)			402.36 (0.000)	

Note(s): [a]RR: Reasonable range of energy intake per capita per day recommended in the 2016 Chinese Dietary Guidelines or Chinese Food Guide Pagoda; [b]The reported t-statistics are the result of the *t*-test comparing rural–suburban migrants with those who moved into urban centers; [c]The reported *z*-statistics are the result of the Mann–Whitney test comparing rural–suburban migrants with those who moved into urban centers; [d]The reported Chi-squared values are the result of the Kruskal–Wallis test to examine whether the nutrition of migrants changes significantly over time; *p*-value in parentheses; $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 2.
Changes in the dietary diversity and energy intake for migrants over time

		Yprotn(%)			Yfat(%)			Ycho(%)[a]	
Year	Overall	Urban	Suburban	Overall	Urban	Suburban	Overall	Urban	Suburban
2000	11.97	12.42	11.96	29.64	31.52	29.59	57.39	54.65	57.47
2004	12.14	13.97	12.00	26.59	33.87	26.05	60.19	50.38	60.91
2006	12.05	13.00	11.97	29.05	32.6	28.75	58.07	52.16	58.57
2009	12.82	13.75	12.74	32.69	32.03	32.74	53.80	54.06	53.78
2011	13.59	14.02	13.55	34.43	39.54	33.88	51.30	46.05	51.87
AMDR[b]	10–20%				20–30%			50–65%	
T-stat. Ha:diff≠0		−6.77***			−6.54***			8.27***	
Z-stat. H0:Murb = Msurb		−7.79***			−6.75***			8.22***	
Kruskal–Wallis $\chi^2(p)$		235.99(0.000)			241.02(0.000)			309.48(0.000)	

Note(s): [a]Ycho is defined as the share of energy intake obtained from carbohydrates and is calculated similarly to Yprotn with the conversion vector of 4 (i.e. 1 g of carbohydrate provides 4kcal of energy); [b]AMDR: Adult macronutrients acceptable range recommended in the 2016 Chinese Dietary Guidelines; Other notes are the same with Table 7

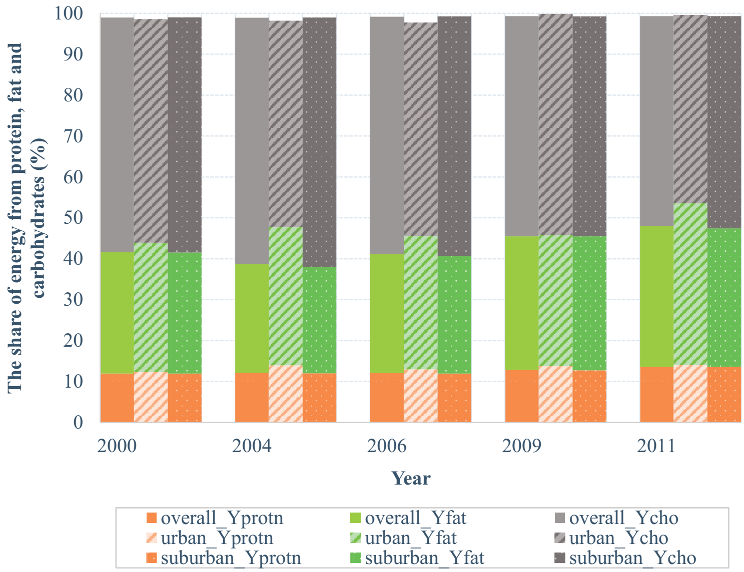
Table 3.
Changes in the structure of energy intake for migrants over time

from 11.97% to 13.59%. The share of energy obtained from fat has increased from 29.64% in 2000 to 34.43% in 2011, which has exceeded the maximum of 30% recommended by the Chinese Dietary Guidelines.

In addition, dietary diversity and nutrition present significant differences between the two subsamples, as evidenced by the *t*-test ($p < 0.01$) and the nonparametric Mann–Whitney test ($p < 0.01$). To be specific, more diverse diets and higher shares of energy from protein and fat were found among migrants living in urban areas compared to those who moved to the suburbs. In terms of the structure of energy, Table 2 and Figure 2 show that the percentages of energy from protein and fat increased, while the intake from carbohydrates decreased.

Specifically, the share of energy obtained from protein for rural–urban migrants increased from 12.42% in 2000 to 14.02% in 2011, while it increased from 11.96% to 13.55% for rural–suburban migrants, with the growth rates of 12.88% and 13.29%, respectively. A similar analysis shows that the growth rate of the share of energy obtained from fat for rural–urban migrants (25.44%) is almost twice as much as that for rural–suburban migrants (14.50%). It is worth noting that the share of energy obtained from fat exceeds the 30% ceiling recommended by the dietary guidelines for the two groups of migrants. Figure 2 also reflects that fat intake contributes significantly to structural changes in energy, which is more pronounced in urban centers.

It is worth noting that the shares of energy from protein and fat have increased, but the absolute intake of protein and fat has not increased, indicating some changes in dietary patterns and specific food groups. Therefore, we compared the per capita consumption of 19 main food items of migrants in 2000 and 2011. The results in Appendix Table A4 show that daily food consumption per capita increased by 61.48 g during 2000–2011, while energy and macronutrients (protein, fat and carbohydrates) intake per capita per day declined by



Notes(s): Energy is mainly provided by three macronutrients (protein, fat, carbohydrates). Yprotn, Yfat and Ycho indicate the shares of energy obtained from protein, fat and carbohydrates, respectively

Figure 2. Changes in the structure of energy intake for total migrants over time

different amounts (490.56 kcal, 6.28 g, 17.16 g, 63.86 g, respectively). This may be mainly because of the large decline in staple food consumption and changes in lifestyle.

In terms of the amount of food consumed, between 2000 and 2011, both vegetable and fruit consumption per capita per day relatively remarkably increased by 41.88 g and 36.96 g, respectively, followed by fast foods (25.58 g), milk and dairy products (15.26 g) and beverages (14.05 g). The consumption of high-quality protein foods such as poultry and eggs increased only slightly by 5.02 g and 2.81 g per capita per day, respectively, while consumption of legumes and their products decreased significantly by 32.82 g during the same period. It is likely that the original close relationship between self-sufficient food and food consumption choices became weaker after rural residents migrated to urban areas (Huang and Bouis, 2001). As a nutritional quantity indicator, energy supplied by cereals has distinctly decreased by 401.28 kcal, and that from fats and oils decreased by 162.49 kcal. This decline is mainly due to the lowered consumption of rice, animal fats and wheat. However, energy from fast foods has increased for migrants, implying that urbanization stimulates the consumption of high-processed and convenient foods. In addition, no significant change appeared in the two major macronutrients (protein and fat) for migrants from 2000 to 2011.

In summary, migrants' consumption of plant-sourced foods such as fruits and vegetables, as well as fast foods and snacks, remarkably increased, and the consumption of animal-sourced foods such as poultry and eggs increased slightly, while there was no significant increase in the consumption of high-protein foods such as aquatic products, fungi and algae.

4.4 Changes in urbanicity over time

As mentioned earlier, the community urbanicity index reflects the development of urban or the degree to which a place exhibits urban features. Overall, the average urbanicity index gradually increased from 58.53 in 2000 to 67.13 in 2011 (Figure 3). Correspondingly, the average urbanicity index of urban centers increased from 76.19 to 90.92, and that of the suburbs increased from 58.01 to 64.57, an increase of 19.33% and 11.31%, respectively. Whether it is an urban center or a suburban area, the community urbanicity index demonstrates an increasing trend, indicating that communities in which rural migrants relocated are increasingly becoming urbanized. In addition, the urbanicity index of urban centers presents a substantial difference from that of suburban areas in each survey year. This also indicates that the development of urban centers is indeed better than in the suburbs, with more conventional markets, infrastructure and adequate medical resources, for instance. This, in turn, suggests that suburbs have a great potential for development, which is of great significance to a large number of migrants moving to suburban areas.

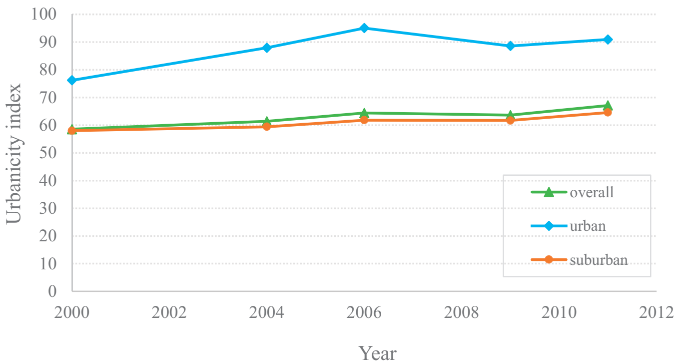


Figure 3.
Changes in the urbanicity index over time

5. Empirical results

Following the models (5)–(7) established earlier, we estimated through both random-effects and fixed-effects regressions, thereafter, conducted the Hausman tests for the full sample to justify which one is suitable. As shown at the bottom of Tables 4–6, the results of all Hausman tests display that the fixed-effects models are favored for estimating dietary diversity and nutrition intake. Thus, Tables 4–6 only report the estimation results of the fixed-effects models. Additionally, we examined the spatial heterogeneity of urbanicity on dietary diversity and nutrition for migrants living in urban centers and those living in suburban areas separately. Model (7) particularly was used for a stepwise estimated by the fixed-effects estimator. The result is presented in Table 5.

5.1 Impact of urbanicity on dietary diversity

The results in Table 4 demonstrate that urbanicity has a statistically significant relationship with dietary diversity for the overall sample and rural–suburban migrants. Specifically, column (1) shows that urbanicity has a significant and positive effect on migrants' dietary diversity at 1% level of significance indicating that improving urbanicity or community environments promote more diverse food consumption among migrants. Interestingly, urbanicity has no significant impact on dietary diversity for migrants living in urban centers (column (2) in Table 4). In contrast, the impact of urbanicity on dietary diversity for migrants living in the suburbs was significant and positive, indicating that rural–suburban migrants experience a notable increase in dietary diversity with the improvement of urbanicity. Therefore, heterogeneity exists in the effect of urbanicity on dietary diversity for rural–urban migrants and rural–suburban migrants.

The possible nonlinear relationship between urbanicity and dietary diversity for the overall sample has also been investigated, and the results are reported in Appendix Table A5. Although the coefficient of urbanicity index on dietary diversity was significant and positive, the square term of urbanicity index on dietary diversity was not significant and negative. Following this, we conducted the exact test for a U-shaped relationship, and the T-value (0.48) indicates that there is no inverse U-shaped relationship between urbanicity and dietary diversity within the range of urbanicity index. As such, the linear relationship between urbanicity and dietary diversity is more appropriate.

5.2 Impact of urbanicity on energy intake

As shown in columns (4)–(6) of Table 4, the urbanicity presents no significant impact on the energy intake of migrants. The T-value (0.73) in Appendix Table A5 also displays that urbanicity index and energy intake have neither U-shaped nor inverse U-shaped relationships.

As demonstrated in model (7), energy intake, as a measurement of nutritional quantity, may be affected by the interaction of urbanicity and income. Table 5 presents the stepwise empirical regression results of energy intake for all migrants by including urbanicity, income and their interactive terms. The urbanicity index in column (1) and (3) does not significantly affect energy intake until an interaction of income and urbanicity is included in the model. Column (4) shows that the interaction effect between the urbanicity index and income is significantly associated with the total energy intake after controlling for other covariates. The coefficients of the urbanicity index and income are -3.76 and -1.34, significant at the 0.05 significance level for all migrants' energy intake, and their interaction effect is 0.35 and significant. This indicates that the marginal effect of the urbanicity index on energy intake depends on the household income per capita, and this marginal effect will be discussed in the following section.

Table 4.
Regression results of dietary diversity and total energy intake

Variables	(1) overall	DDS (2) urban	(3) suburban	(4) overall	Ln energy (5) urban	(6) suburban
Index	0.017*** (0.006)	−0.012 (0.035)	0.018*** (0.006)	−0.0005 (0.001)	0.004 (0.008)	0.0001 (0.001)
Lnhhinc	0.470* (0.283)	−2.696** (1.341)	0.577** (0.290)	0.081* (0.045)	0.308* (0.185)	0.066 (0.047)
Age	−0.636*** (0.181)	0.032 (0.812)	−0.685*** (0.184)	0.037 (0.029)	0.133 (0.091)	−0.002 (0.029)
Educ						
Middle	−0.099 (0.132)	2.677*** (0.926)	−0.103 (0.132)	0.025 (0.022)	0.921*** (0.117)	0.023 (0.022)
High or technical	−0.244 (0.190)	−2.205 (2.020)	−0.226 (0.190)	−0.044 (0.037)	−0.135 (0.405)	−0.043 (0.037)
University or higher	0.292 (0.532)	−1.187 (1.871)	0.224 (0.585)	−0.084 (0.113)	−0.059 (0.407)	−0.145 (0.132)
Married	0.536** (0.210)	−0.470 (1.221)	0.520** (0.213)	0.086** (0.034)	−0.066 (0.147)	0.087** (0.034)
Hhsize	0.145*** (0.037)	0.685** (0.272)	0.132*** (0.037)	−0.009 (0.006)	−0.031 (0.036)	−0.010 (0.006)
Fafh	0.002 (0.023)	0.041 (0.149)	−0.002 (0.023)	−0.008** (0.004)	0.002 (0.015)	−0.008** (0.004)
Phyact						
Moderate	0.189 (0.117)	0.102 (0.430)	0.191 (0.122)	0.041** (0.019)	0.100 (0.070)	0.050** (0.020)
Heavy	−0.055 (0.110)	−0.917** (0.435)	−0.056 (0.111)	0.050** (0.019)	0.301*** (0.083)	0.048** (0.020)
Year						
2004	2.542*** (0.718)	1.586 (3.469)	2.718*** (0.730)	−0.151 (0.115)	−0.719* (0.406)	0.007 (0.117)
2006	4.366*** (1.074)	2.411 (5.013)	4.649*** (1.091)	−0.256 (0.171)	−1.122* (0.588)	−0.010 (0.175)
2009	6.733*** (1.618)	2.556 (7.473)	7.146*** (1.645)	−0.434* (0.258)	−1.285 (0.868)	−0.086 (0.264)
2011	8.384*** (1.977)	2.987 (9.254)	8.907*** (2.004)	−0.689** (0.315)	−1.732 (1.063)	−0.269 (0.322)
_cons	24.595*** (7.769)	33.312 (35.053)	25.473*** (7.932)	5.269*** (1.281)	−1.125 (4.213)	6.988*** (1.311)
N	4,469	335	4,134	4,469	335	4,134
R^2 (within)	0.152	0.261	0.153	0.134	0.233	0.146
Hausman test (χ^2)	111.86***			68.92***		

Note(s): Robust standard errors in parentheses; $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 5. Regression results of total energy intake for the overall migrants

Variables	(1)	(2)	(3)	(4)
Lnindex	−0.011 (0.061)		−0.019 (0.061)	−3.758** (1.749)
Lnhhinc		0.081* (0.045)	0.081* (0.045)	−1.342** (0.674)
Lnindex*Lnhhinc				0.346** (0.162)
Age	0.030 (0.028)	0.037 (0.029)	0.037 (0.029)	0.037 (0.029)
Educ				
Middle	0.013 (0.021)	0.025 (0.022)	0.025 (0.022)	0.025 (0.022)
High or technical	−0.048 (0.036)	−0.044 (0.037)	−0.044 (0.037)	−0.046 (0.037)
University or higher	−0.091 (0.115)	−0.085 (0.114)	−0.085 (0.114)	−0.095 (0.113)
Married	0.064* (0.033)	0.085** (0.033)	0.086** (0.034)	0.084** (0.033)
Hhsize	−0.010 (0.006)	−0.009 (0.006)	−0.009 (0.006)	−0.010 (0.006)
Fafh	−0.006* (0.004)	−0.008** (0.004)	−0.008** (0.004)	−0.007* (0.004)
Phyact				
Moderate	0.033* (0.019)	0.041** (0.019)	0.041** (0.019)	0.042** (0.019)
Heavy	0.050*** (0.019)	0.051*** (0.019)	0.050** (0.019)	0.050** (0.019)
Year	Yes	Yes	Yes	Yes
_cons	6.467*** (1.145)	5.240*** (1.278)	5.312*** (1.303)	20.679*** (7.306)
N	4,469	4,469	4,469	4,469
R^2	0.130	0.134	0.134	0.136
Hausman test (χ^2)	65.13***	43.32***	66.46***	65.27***

Note(s): Robust standard errors in parentheses; $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 6. Regression results of the share of energy obtained from protein and fat

Variables	Yprotn (1) overall	(2) urban	(3) suburban	Yfat (4) overall	(5) urban	(6) suburban
Index	0.124*** (0.043)	−0.199 (0.618)	0.135*** (0.047)	0.465*** (0.163)	8.516*** (2.614)	0.516*** (0.178)
Index^2	−0.001*** (0.0003)	0.002 (0.003)	−0.001*** (0.000)	−0.004*** (0.001)	−0.049*** (0.015)	−0.005*** (0.001)
Lnhhinc	−0.255 (0.413)	4.366** (1.870)	−0.410 (0.423)	−0.468 (1.669)	1.215 (11.249)	−0.491 (1.684)
Age	0.081 (0.260)	0.223 (0.919)	0.113 (0.278)	−0.549 (1.082)	−4.814 (3.805)	−0.190 (1.156)
Educ						
Middle	−0.487** (0.203)	1.967** (0.991)	−0.507** (0.204)	−0.348 (0.784)	−26.499*** (4.880)	−0.254 (0.785)
High or technical	−0.389 (0.307)	2.516 (3.315)	−0.425 (0.308)	−2.729** (1.224)	−3.040 (14.299)	−2.712** (1.238)
University or higher	−0.699 (0.879)	2.495 (3.289)	−0.902 (1.134)	−4.975 (4.437)	−1.537 (14.166)	−4.360 (5.560)
Married	0.151 (0.306)	1.114 (1.116)	0.127 (0.315)	−0.817 (1.413)	−9.206 (6.729)	−0.047 (1.401)
Hhsize	0.060 (0.057)	0.420 (0.297)	0.051 (0.058)	−0.168 (0.237)	−0.665 (1.370)	−0.115 (0.242)
Fafh	0.125*** (0.036)	−0.167 (0.118)	0.138*** (0.037)	0.259* (0.140)	0.456 (0.749)	0.256* (0.142)
Phyact						
Moderate	0.033 (0.175)	−0.513 (0.544)	0.030 (0.187)	−0.329 (0.749)	1.560 (3.033)	−0.881 (0.771)
Heavy	−0.485*** (0.173)	1.250 (1.097)	−0.481*** (0.174)	−0.435 (0.671)	−5.687 (4.420)	−0.586 (0.676)
Year						
2004	−0.212 (1.050)	0.090 (4.172)	−0.369 (1.120)	−0.352 (4.329)	9.910 (17.143)	−1.874 (4.609)
2006	−0.653 (1.548)	−2.963 (5.810)	−0.833 (1.656)	2.542 (6.428)	20.875 (24.496)	0.423 (6.874)
2009	−0.168 (2.330)	−2.533 (8.457)	−0.413 (2.489)	7.160 (9.707)	32.328 (36.163)	4.146 (10.359)
2011	0.184 (2.853)	−3.812 (10.536)	−0.102 (3.043)	9.013 (11.811)	47.687 (44.382)	5.163 (12.588)
_cons	7.765 (11.245)	−40.311 (41.853)	7.861 (12.070)	48.250 (45.860)	−136.766 (194.576)	31.678 (49.221)
N	4,469	335	4,134	4,469	335	4,134
R^2(within)	0.058	0.209	0.061	0.049	0.178	0.053
Hausman test (χ^2)	37.98***			26.04**		
T-value[a]	2.11**			2.19**		

Note(s): [a]The *T*-value here tests the presence of an inverse *U*-shape; Robust standard errors in parentheses; $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

5.3 Impact of urbanicity on the share of energy from protein and fat

As described by the empirical strategy, the linear relationship of urbanicity with the shares of energy obtained from protein and fat was estimated separately. The results in Appendix Table A5 reveal no significant effect of urbanicity on the shares of energy from both protein and fat for all migrants.

We further explored the nonlinear relationship between urbanicity and the energy shares obtained from protein and fat. The results are reported in Table 6. The *T*-values (2.11, 2.19) in columns (1) and (4) indicate that an inverse *U*-shaped relationship exists between urbanicity and energy shares from both protein and fat for the overall sample. Specifically, the coefficients of the urbanicity index to protein energy (0.124) and its squared term (−0.001) are statistically significant at a 1% (column (1)). This regression result indicates that increasing community urbanicity is associated with increasing energy from protein, but the positive effect is smaller with a larger change in urbanicity, that is, urbanicity promotes an increase in the share of energy derived from protein at a decreasing rate, which is consistent with Jones-Smith and Popkin (2010). Similarly, the coefficients of the urbanicity index to fat energy (0.465) and its squared term (−0.004) are statistically significant at a 1% (column (4)). This also indicates that urbanicity increases migrants' energy from fat, but the positive effect gradually declines with an increase in the community urbanicity index.

Further heterogeneity analysis indicates different impacts of urbanicity on the shares of total energy intake from protein and fat. Specifically, a nonlinear and significant relationship between urbanicity and the share of energy from protein exists in rural–suburban migrants, but it is not significant in migrants who moved to urban centers. Interestingly, household income per capita presents a significant impact on the share of energy from protein for those migrants living in urban centers. Columns (5) and (6) show that the regression results of the two groups appear to be somewhat similar and display an inverse *U*-shaped, but have a different degree of impact of urbanicity.

In addition, a number of other variables were also found to significantly affect the dietary diversity and nutrition of migrants. As expected, the coefficient of columns (1) and (4) in Table 4 indicates that migrants with higher incomes prefer to consume more diverse foods and more energy. Older migrants tend to consume fewer types of food. Married migrants tend to have higher dietary diversity and energy intake than unmarried ones. Moreover, dietary diversity increases significantly with the increase in the number of family members and the total energy decreases significantly with an increase in the frequency of dining out. The latter also has a positive and significant effect on the shares of energy obtained from protein and fat, especially for migrants living in suburban areas.

5.4 Robustness check

The present paper uses nonexperimental data to evaluate the impact of urbanicity on energy intake and nutritional intake of rural–urban migrants; hence there is a problem of selection bias, which undermines the validity causality. We use PSM as it minimizes selection bias (Cochran and Rubin, 1973; Rosenbaum and Rubin, 1983).

PSM permits matching each treated migrant with a similar nontreated individual(s) (control individuals) and compares the average difference in the outcome variables. In the current paper, the outcome variables are dietary diversity, total energy intake, the share of protein and the share of fat. In order to analyze the impact of urbanicity on dietary diversity and nutrition, we created treated and control groups. Based on the level of urbanicity index, we divided the sample into five urban quintiles. In the first PSM estimation, we used the individuals in quintiles 2–5 (more than 45.58) as treated and quintile 1 (less than 45.58) as control; in the second estimation, we used 1–2 (less than 54.58) as control and 3–5 (54.58) as treated; in the third estimation, we used 1–3 (less than 68.25) as control and 4–5 (more than

68.25) as treated; and in the final estimation, we used 1–4 (less than 82.75) as control and 5 (more than 82.75) as treated. To check the sensitivity of the treatment effect, we evaluate the result using the propensity scores from three different approaches (1, 5 and 10 nearest neighbors, radius and kernel density). The results are reported in Table 7, and the corresponding test results of matching quality are presented in Appendix Table A6.

The PSM estimation indicates that the individuals living in locations with higher urbanicity (treatment group) have significantly higher dietary diversity, total energy intake, the share of protein and the share of fat. The result shows that the impact of urbanicity on dietary diversity, total energy intake and share of protein and fat is positive and significant at all the four cutoff points (45.58, 54.58, 68.25, 82.75) and all the matching algorithms (nearest neighbor, kernel and radius) at 1% level of significance, which highlights the positive influence of urbanicity on nutrition among migrants.

The absolute value of the impact of urbanicity on dietary diversity increases across the different cutoff points for the treated and control, while the impact of urbanicity on total energy intake, the share of protein and fat initially decreases and increases from quartile 3 (68.82).

6. Discussions

6.1 The marginal effect of urbanicity on energy intake

The significant and positive coefficient of interaction variable between urbanicity and income, as given in Table 5, suggests that the marginal effect of urbanicity on energy intake, which can be understood as the elasticity of calorie-urbanicity, depends on the income level. As shown in Figure 4, the average marginal effect of urbanicity on energy intake varies with the value of the conditioning variable of income. The calculation in Appendix B1 and Figure 4 shows that the threshold for the logarithm of income is 10.86 when the marginal effect of urbanicity on energy intake equals to zero, indicating that at that point, changing urbanicity does not change energy intake. When the logarithm of income is less than 10.86, the marginal effect of urbanicity is negative, which weakens gradually as the income increases. Thus improving the urbanicity without increasing the income will reduce energy intake. However, when the logarithm of income exceeds 10.86, the marginal effect of urbanicity becomes significantly positive and grows in strength as the income increases, and the energy intake increases with the urbanization.

This indicates that improving the urbanicity of residential communities will not help increase the energy intake of migrants with relatively low household income per capita. However, it will have a positive effect on energy intake for migrants when their household income per capita achieves its threshold or breakeven point, that is, CNY 52,052 in this study. Generally, low-income migrants mainly live in low-urbanized communities such as the suburbs, and they are more vulnerable to be affected by rural household registration (Han *et al.*, 2019). However, increasing community urbanicity means more expenditures on social public services, thereby reducing their food expenditures and demand for energy intake and nutritious food. In contrast, high-income migrants care more about community environment and development; therefore, increasing urbanicity makes it more convenient to access more diverse and processed food to obtain more energy. To sum up, with income growth, the positive impact of urbanicity on energy intake will be strengthened. This provides important information for policymakers that being overweight and obese due to excessive energy intake in highly urbanized regions should be paid more attention to, especially for the high-income groups in developed cities.

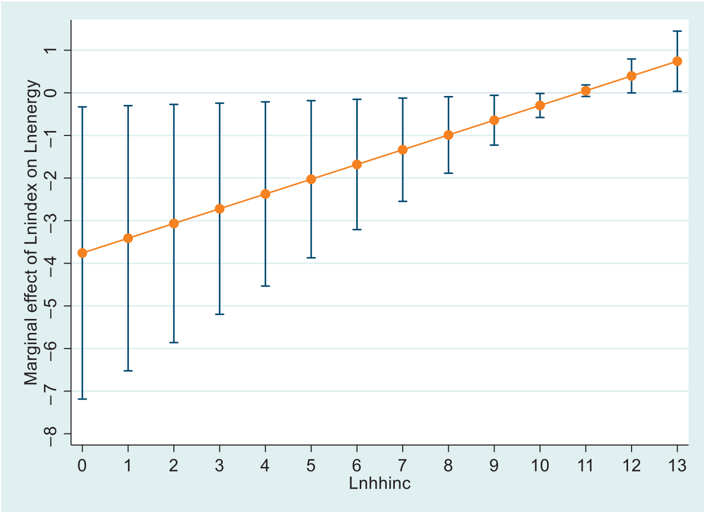
6.2 The marginal effect of urbanicity on the shares of energy from protein and fat

As mentioned earlier , urbanicity and the shares of energy from protein and fat present an inverse *U*-shaped relationship (shown in Figure 5). Specifically, the share of energy obtained

Table 7. The treatment effect of urbanicity on nutrition for different treated groups

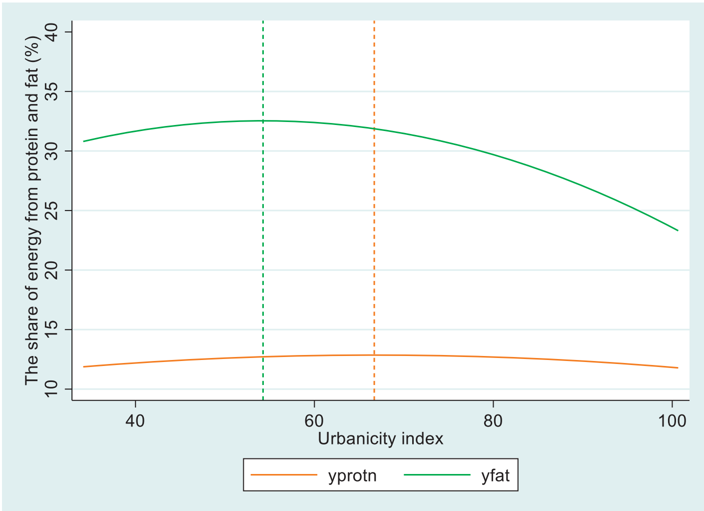
		ATT[a]	*T*-stat	ATT[b]	*T*-stat	ATT[c]	*T*-stat	ATT[d]	*T*-stat
NN (1)	DDS	1.56 (0.11)	14.64***	1.46 (0.10)	14.08***	1.24 (0.11)	11.55***	1.17 (0.13)	8.71***
	Lnenergy	0.07 (0.02)	3.20***	0.07 (0.02)	3.86***	0.09 (0.02)	4.85***	0.07 (0.02)	3.20***
	Yprotn	1.18 (0.17)	6.81***	0.57 (0.15)	3.83***	0.96 (0.15)	6.56***	1.06 (0.19)	5.58***
	Yfat	3.17 (0.74)	4.29***	2.39 (0.60)	4.01***	3.27 (0.59)	5.51***	3.88 (0.71)	5.50***
NN (5)	DDS	1.57 (0.10)	16.26***	1.43 (0.09)	15.84***	1.24 (0.09)	13.20***	1.18 (0.11)	10.62***
	Lnenergy	0.07 (0.02)	3.18***	0.08 (0.02)	4.60***	0.08 (0.02)	5.31***	0.08 (0.02)	4.90***
	Yprotn	1.16 (0.16)	7.23***	0.63 (0.13)	5.03***	0.93 (0.13)	7.32***	0.94 (0.15)	6.14***
	Yfat	3.20 (0.67)	4.79***	2.39 (0.53)	4.47***	2.63 (0.52)	5.07***	3.97 (0.56)	7.03***
NN (10)	DDS	1.58 (0.10)	16.31***	1.42 (0.09)	15.89***	1.25 (0.09)	13.35***	1.18 (0.11)	10.80***
	Lnenergy	0.07 (0.02)	3.10***	0.08 (0.02)	4.79***	0.08 (0.02)	5.32***	0.08 (0.02)	4.73***
	Yprotn	1.17 (0.16)	7.32***	0.61 (0.13)	4.89***	0.92 (0.13)	7.31***	0.97 (0.15)	6.44***
	Yfat	3.19 (0.67)	4.76***	2.42 (0.53)	4.54***	2.70 (0.52)	5.22***	4.16 (0.56)	7.46***
Radius	DDS	1.58 (0.10)	16.31***	1.42 (0.09)	15.89***	1.25 (0.09)	13.45***	1.19 (0.11)	11.04***
	Lnenergy	0.07 (0.02)	3.10***	0.08 (0.02)	4.77***	0.08 (0.02)	5.38***	0.08 (0.02)	4.69***
	Yprotn	1.17 (0.16)	7.32***	0.61 (0.13)	4.89***	0.92 (0.13)	7.34***	1.00 (0.15)	6.68***
	Yfat	3.19 (0.67)	4.76***	2.41 (0.53)	4.53***	2.69 (0.52)	5.21***	4.16 (0.55)	7.51***
Kernel	DDS	1.61 (0.09)	18.64***	1.47 (0.08)	17.44***	1.29 (0.09)	14.61***	1.26 (0.10)	12.37***
	Lnenergy	0.06 (0.02)	2.96***	0.08 (0.02)	5.39***	0.09 (0.01)	5.90***	0.08 (0.02)	5.44***
	Yprotn	1.08 (0.14)	7.49***	0.72 (0.12)	6.11***	0.97 (0.12)	8.19***	0.96 (0.14)	6.93***
	Yfat	3.15 (0.61)	5.19***	2.44 (0.50)	4.87***	2.66 (0.49)	5.41***	4.14 (0.52)	8.03***

Note(s): Matching is performed within common support. For nearest neighbor (NN) matching and radius matching, the caliper was set at 0.001 to reduce potential matching bias. [a, b, c, d]means the ATT of urbanicity index across its quantiles. ***Significant at the 1% level



Note(s): The orange line indicates the average marginal effect; the blue line indicates the 95% confidence interval

Figure 4.
The average marginal effect of urbanicity on the energy intake for total migrants with the change of household income per capita (all in the natural logarithm form). A color version of this figure is available online



Note(s): Yprotn and yfat are the shares of energy intake from protein and fat, respectively. The orange and green dashed lines indicate that the urbanicity index values are 66.69 and 54.26, respectively, when the shares of energy from protein and fat reach the maximum

Figure 5.
Nonlinear effects of urbanicity on the shares of energy intake from protein and fat for total migrants. A color version of this figure is available online

from protein increases with the development of urbanicity, until reaching its threshold of 66.69 (orange dashed line in Figure 5). When the urbanicity index is less than 66.69, the marginal effect of urbanicity is significantly positive, and the share of energy obtained from protein increases with the improvement of urbanicity. When urbanicity continues to improve and exceeds its threshold of 66.69, the marginal effect of urbanicity is significantly negative and the share of energy obtained from protein decreases. This indicates that, to some extent, the development of urbanicity improves the quality or structure of energy, although it is not permanent.

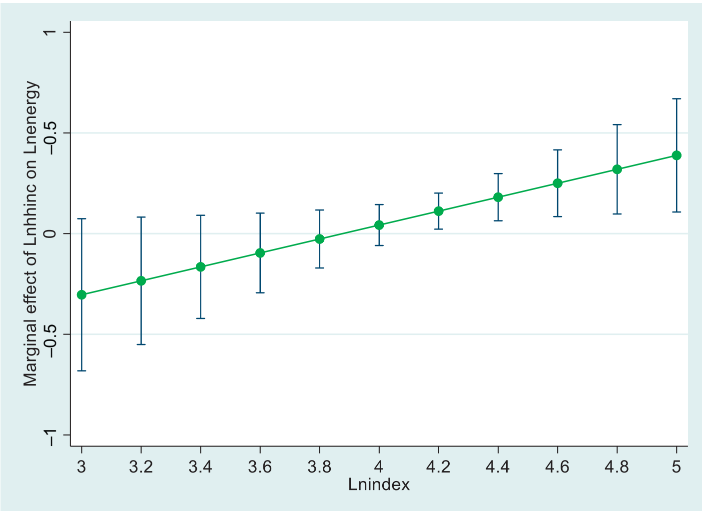
Similarly, the threshold value of urbanicity on the share of energy obtained from fat is 54.26 (green dashed line in Figure 5). The effect of the urbanicity index on the share of energy from fat increases with the improvement in the urbanicity index until 54.26 and then decreases with improvement in the urbanicity index.

The results also show that the average urbanicity index is 63.10 (Table 1), and the share of energy provided by protein is on the rise, while the share of energy provided by fat has exceeded 30%, beyond the level recommended by the 2016 Chinese Dietary Guidelines. This demonstrates that developing urbanicity helps improve the nutritional structure to a certain extent. Furthermore, given the significant nutrition gap between urban and suburbs, the policy for enhancing the nutritional quality should target less developed communities or suburbs.

6.3 The marginal effect of income on energy intake

In the present paper, we consider the marginal effect of income on energy intake, which is consistent with urbanicity and energy intake. The regression results in Table 5 show that the marginal effect of income on energy intake varies with the improvement of urbanicity, thereby indicating a clear nonlinear relationship between income and energy intake. In fact, the marginal effect of income on energy intake in this study can be interpreted as the elasticity of calorie income.

The calculation in Appendix B2 and Figure 6 shows that the threshold for the logarithm of urbanicity index is 3.88 when the average marginal effect of income on energy intake equals to zero, indicating that changing the income does not change the energy intake. When the



Note(s): The green line indicates the average marginal effect; the blue line indicates the 95% confidence interval

Figure 6. The average marginal effect of income on the energy intake for total migrants with the change of urbanicity index (all in the natural logarithm form). A color version of this figure is available online

logarithm of urbanicity index is less than 3.88, the average marginal effect of income is negative, which gradually weakens as the urbanicity develops and the energy intake decreases as income increases without improvement in the urbanicity. However, when the logarithm of urbanicity index exceeds 3.88, the average marginal effect of income becomes significantly positive and grows in strength with the development of urbanicity and the energy intake increases with the improvement of income. When the logarithm of urbanicity index is at its average level of 4.11 (Table 1), for an increase of 1% in income, the daily total energy intake increases by 0.08%. That is, the calorie–income elasticity is 0.08 when the logarithm of urbanicity is 4.11. When the logarithm of index achieves its maximum value (4.61) in this study, the calorie–income elasticity increases to 0.26. Interestingly, the calorie–income elasticity changes with the development of urbanicity.

The analysis of the marginal effects of income suggests that increasing household income per capita will not help increase the energy intake of migrants in less developed communities. However, it will work when the average urbanicity index achieves its threshold or breakeven point, that is, 48.38 in this study. In the low-urbanized communities such as suburbs, the costs of accessing diverse and nutritious food increase, thus reducing migrants' willingness to consume. In contrast, in high-urbanized communities, foods are well processed and more diverse. Migrants with high income can thus choose from more processed foods and obtain more total energy. In summary, with the development of urbanicity, the positive impact of income on energy intake increases. However, more attention should be paid to the relatively poor residents in less developed communities.

The earlier analysis of the marginal effect of income on total energy intake has an important implication for future research on residents' dietary patterns and nutrition, especially for rural–urban migrants. To plan the process of dietary restructuring, it is important to understand how residents in different income brackets allocate income to various food expenditures so as to guide how the government should set reasonable fiscal and taxation policies to in turn encourage healthy consumption patterns.

6.4 Future researches under the urban–rural integration development

With rapid urbanization and the active implementation of the Rural Revitalization Strategy, changes have been taking place, the flow of input elements such as labor, land, capital, information and technology between urban and rural areas is accelerating integration. The Chinese Government has also made a major strategic deployment, clearly proposing to establish and improve the system of urban–rural integration development. In this context, it is worth conducting further research on the prediction of population and food demand. It is also essential to investigate whether the population structure of urban and rural areas will reach a stable level in the future and whether the food consumption and nutritional status among urban and rural residents will present a similar trend with the development and promotion of urban–rural integration. In-depth research on whether and how urban–rural integration in China will affect food consumption and nutrition in the future is another interesting research domain.

7. Conclusions and policy implications

China has been going through rapid economic transformation and urbanization, which have contributed to an increase in income, changes in the food system and nutritional status. Therefore, this study underlines the importance of urbanicity on rural–urban migrants' dietary diversity and nutrition intake and provides useful policy information for improving the nutritional status of the migrants from the perspective of urban development. The descriptive statistics reveal that the rural–urban migrants have experienced increased exposure to diverse and convenient foods and that migrants consume more diverse food than the rural–suburban migrants. However, compared to the urban dwellers, the rural–urban migrants have significantly less diverse food and lower nutrition intake.

The linear regression result shows that the migrants in the more urbanized city consume a greater variety of food, while urbanicity has no significant impact on the energy intake and its share from protein and fat. Furthermore, the estimation results with the interaction of urbanicity and income indicate that the marginal effects of urbanicity on energy intake vary with per capita household income. Therefore improving community urbanicity may significantly improve the energy intake for migrants if the per capita household income also increases. Specifically, energy intake decreases with the improvement of community urbanicity for those migrants whose per capita household income is less than CNY 52,052, while it increases with the improvement of community urbanicity for those migrants whose per capita household income is higher than CNY 52,052. This implies that malnutrition of being overweight and obese, caused by excessive energy intake in highly urbanized regions, requires more attention, especially for the high-income groups in developed cities.

The results of nonlinear relationship regression indicate that there is no significant U-shaped relationship between urbanicity and dietary diversity as well as urbanicity and energy intake. However, there is an explicit inverse *U*-shaped relationship between urbanicity and the share of energy from protein, as well as urbanicity and the share of energy from fat. The inverse *U*-shaped relationship reveals that improving community urbanicity promotes an increase in the shares of energy obtained from protein and fat at a decreasing rate, until reaching the urbanicity index threshold of 66.69 and 54.26, respectively. It is worth noting that the share of energy from fat has exceeded 30%, a reasonable value recommended by the 2016 Chinese Dietary Guidelines and the China Food and Nutrition Development Program (2014–2020). This suggests that developing urbanicity helps improve the nutritional quality to a certain extent.

The findings of this study provide a better understanding of urbanicity and nutrition for rural–urban migrants and imply that policies should be proposed and implemented to improve health in China. The differences in food consumption and nutrition between rural–urban migrants and local urban dwellers should be emphasized to realize a healthy China. Given the significant nutrition gap between urban centers and suburbs, less developed communities or suburbs should get enough attention to improve nutritional quality. In contrast, the nutrition issues of overweight and obesity in more urbanized regions should not be neglected. It is important to control high-fat, high-sugar and high-processed foods consumption and keep a balanced diet considering the increasing proportion of energy from fat. Moreover, there is a need to shift food policies' focus away from energy-dense foods and toward nutrient-rich foods, improve access to food markets and build a more urbanized community environment with more medical services, educational institutions, convenient public infrastructures and so on.

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Appendix 1

Food group	Food items
Cereals	Wheat
	Rice
	Corn
	Barley
	Millet
	Others
Tubers and starches	Tubers
	Starches
Legumes	Soy bean
	Mung bean
	Adzuki bean
	Kidney bean
	Broad bean
	Others
Vegetables	Root vegetable
	Leguminous vegetable and sprout
	Cucurbitaceous and solanaceous vegetable
	Allium vegetable
	Stem, leafy and flowering vegetable
	Aquatic vegetable
	Tuber
	Wild vegetable
Fungi and algae	Fungus
	Alga
Fruits	Kernel fruit
	Drupe fruit
	Berry
	Citrus fruit
	Tropical fruit
	Melons
Nuts and seeds	Nut
	Seed
Meat	Pork
	Beef
	Goat
	Others
Poultry	Chicken
	Duck
	Others
Milk and dairy	Liquid milk
	Milk powder
	Yogurt
	Others
Eggs	Chicken egg
	Duck egg
	Others

(*continued*)

Table A1. Food groups and subgroups in the food composition table

Food group	Food items
Aquatic products	Fish
	Shrimp
	Crab
	Shellfish
	Others
Snacks and cakes	Snack
	Cake
Fast foods	Handy food
	Convenience food and ice cream
	Others
Liquor and alcoholic beverages	
Sugars and preserves	Sugars
	Candy
	Preserves
Fats and oils	Animal fat
	Vegetable oil
Condiments	Soy Sauce
	Vinegar
	Sauce
	Fermented soybean curd
	Pickles
	Spice
	Salt and others

Table A1.

Nutrition	Migrants Overall	Migrants 2000	Migrants 2011	Urban dwellers Overall	Urban dwellers 2000	Urban dwellers 2011	*T*-stat.[a] Overall	*T*-stat.[a] 2000	*T*-stat.[a] 2011
DDS[b]	6.97	6.09	7.95	8.46	7.31	9.56	−38.02***	−17.13***	−19.51***
Energy (kcal/p/d)	2051.33	2235.56	1728.04	2031.10	2176.84	1874.16	1.45	2.41**	−3.69***
Protein (g/p/d)	63.53	66.61	58.18	69.11	71.35	67.71	−12.74***	−5.26***	−9.91***
Fat (g/p/d)	70.76	75.25	67.61	81.44	83.92	81.80	−8.29***	−5.70***	−3.63***
Yprotn (%)[c]	12.55	11.97	13.59	13.92	13.19	15.13	−26.73***	−12.49***	−12.90***
Yfat (%)[c]	30.65	29.64	34.43	35.01	34.05	36.80	−22.17***	−10.35***	−5.69***

Note(s): [a]The reported *t*-statistics are the result of a *t*-test comparing the mean nutrition intake of rural–urban migrants with that of urban dwellers; [b]DDS is the number of food items consumed per capita per day; [c]Yprotn and Yfat are the shares of energy obtained from protein and fat, respectively; $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A2. Nutrition comparison of migrants and urban dwellers

Variables	DDS	Lnenergy	Yprotn	Yfat	Index	Lnhhinc	Age	Primary	Middle	High	University	Married	Hhsize	Fafh	Light	Moderate	Heavy
DDS	1.000																
Lnenergy	0.110	1.000															
Yprotn	0.329	−0.154	1.000														
Yfat	0.202	0.077	−0.074	1.000													
Index	0.444	−0.011	0.244	0.210	1.000												
Lnhhinc	0.127	0.030	0.069	0.061	0.114	1.000											
Age	−0.090	−0.164	−0.045	0.013	−0.038	0.006	1.000										
Primary	−0.176	−0.045	−0.102	−0.030	−0.177	−0.068	0.400	1.000									
Middle	0.064	0.053	0.031	0.025	0.010	0.000	−0.233	−0.701	1.000								
High	0.126	−0.000	0.076	0.003	0.174	0.075	−0.196	−0.411	−0.303	1.000							
University	0.089	−0.020	0.065	0.016	0.148	0.047	−0.136	−0.143	−0.105	−0.062	1.000						
Married	−0.008	0.003	−0.005	−0.010	−0.037	−0.012	0.302	0.171	−0.027	−0.139	−0.159	1.000					
Hhsize	0.023	−0.053	0.013	−0.042	−0.057	−0.099	−0.119	0.007	−0.012	0.007	−0.004	−0.071	1.000				
Fafh	0.139	−0.003	0.121	0.072	0.062	0.063	−0.131	−0.145	0.051	0.098	0.093	−0.091	−0.022	1.000			
Light	0.224	−0.194	0.180	0.149	0.424	0.061	0.179	−0.073	−0.018	0.093	0.082	0.008	−0.074	0.022	1.000		
Moderate	0.095	0.026	0.058	0.026	0.038	0.010	−0.175	−0.108	0.063	0.059	0.020	−0.100	0.057	0.083	−0.412	1.000	
Heavy	−0.303	0.177	−0.229	−0.172	−0.462	−0.069	−0.044	0.160	−0.031	−0.141	−0.100	0.070	0.030	−0.088	−0.693	−0.371	1.000

Table A3. Correlation matrix of nutrition and independent variables

Table A4.
Changes in dietary structure and nutrients for migrants in 2000 and 2011

	Δfc (g/p/d)	Δenergy (kcal/p/d)	Δprotein (g/p/d)	Δfat (g/p/d)	Δcho (g/p/d)
Total	61.48	−490.56	−6.28	−17.16	−63.86
Cereals	−3.37	−401.28	−9.37	−0.31	−87.11
Wheat	−5.58	−45.76	−1.26	0.40	−9.56
Rice	−5.25	−347.74	−8.04	−0.61	−76.43
Corn	2.74	−5.78	−0.04	−0.11	−0.69
Barley	−0.23	−0.71	−0.02	0.00	−0.14
Millet	5.60	1.14	0.04	0.03	0.22
Others	−0.65	−2.43	−0.06	−0.02	−0.50
Tubers and starches	−2.36	−3.79	0.14	−0.21	−0.22
Legumes	−32.82	−12.16	−1.78	−0.13	−0.27
Vegetables	41.88	3.58	1.13	0.19	4.31
Fungi and algae	3.50	2.41	0.17	0.03	0.84
Fruits	36.96	16.73	0.21	0.07	4.42
Nuts and seeds	1.03	4.08	0.07	0.40	0.33
Meat	0.42	−26.08	1.17	−3.32	−0.26
Pork	−0.23	−25.78	0.94	−3.13	−0.35
Beef	0.30	−0.82	0.14	−0.20	0.08
Goat	0.10	0.19	0.03	0.00	0.00
Others	0.25	0.32	0.06	0.01	0.00
Poultry	5.02	9.88	1.00	0.61	0.09
Chicken	3.32	5.10	0.70	0.22	0.07
Duck	0.89	2.56	0.15	0.21	0.01
Others	0.82	2.22	0.14	0.18	0.01
Milk and dairy	15.26	9.47	0.42	0.48	0.87
Eggs	2.81	3.51	0.46	0.05	0.26
Aquatic products	−0.06	−1.55	0.06	−0.16	−0.11
Snacks and cakes	6.62	16.07	0.40	0.42	2.83
Fast foods	25.58	67.43	1.96	2.74	9.36
Beverages	14.05	13.95	1.06	0.10	2.68
Liquor and alcoholic beverages	−5.04	−6.70	−0.04	0.00	0.04
Sugars and preserves	0.40	1.96	0.02	0.09	0.27
Fats and oils	−18.02	−162.49	0.00	−18.15	0.11
Animal fat	−18.06	−165.08	0.00	−18.50	0.28
Vegetable oil	0.04	2.59	0.00	0.35	−0.17
Condiments	−30.39	−25.58	−3.35	−0.04	−2.30

Note(s): All the values in the table are calculated for food consumption in 2011 minus that in 2000; the "fc" in column 2 is defined as migrants' food consumption per capita per day; the "cho" in the last column is defined as migrants' carbohydrates consumption per capita per day

Variables	DDS_FE	Lnenergy_FE	Yprotn_FE	Yfat_FE
Index	0.057** (0.025)	0.004 (0.005)	0.009 (0.010)	−0.064 (0.039)
Index^2	−0.0003 (0.000)	−0.000 (0.000)		
Lnhhinc	0.458 (0.283)	0.079* (0.045)	−0.220 (0.415)	−0.308 (1.675)
Age	−0.654*** (0.180)	0.035 (0.029)	0.134 (0.261)	−0.305 (1.089)
Educ				
Middle	−0.095 (0.131)	0.025 (0.022)	−0.498** (0.204)	−0.399 (0.791)
High or technical	−0.232 (0.190)	−0.042 (0.038)	−0.424 (0.304)	−2.892** (1.222)
University or higher	0.319 (0.528)	−0.081 (0.112)	−0.776 (0.861)	−5.331 (4.558)
Married	0.549*** (0.209)	0.088*** (0.034)	0.115 (0.304)	−0.985 (1.426)
Hhsize	0.146*** (0.037)	−0.009 (0.006)	0.057 (0.057)	−0.184 (0.235)
Fafh	0.004 (0.023)	−0.007* (0.004)	0.118*** (0.036)	0.226 (0.139)
Phyact				
Moderate	0.183 (0.116)	0.040** (0.019)	0.050 (0.175)	−0.250 (0.752)
Heavy	−0.057 (0.110)	0.050** (0.019)	−0.479*** (0.173)	−0.410 (0.673)
Year	YES	YES	YES	YES
_cons	24.295*** (7.769)	5.231*** (1.277)	8.636 (11.261)	52.268 (46.041)
N	4,469	4,469	4,469	4,469
R^2 (within)	0.152	0.134	0.054	0.044
Hausman test (χ^2)	92.09***	67.72***	36.13***	58.77***
T-value[a]	0.48	0.73		

Note(s): [a]The *T*-value is the result of a test for a *U*-shaped relationship; Robust standard errors in parentheses; $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table A5. Regression results of nutrition for migrants

Variable	% Bias after different algorithm matching Q(1)	Q(2)	Q(3)	Q(4)
Lnhhinc	18.4*** (12.52)	2.0 (0.68)	1.2 (0.55)	3.1 (1.03)
Age	−4.4* (−1.71)	2.5 (0.83)	2.1 (0.55)	2.1 (0.41)
Gender	9.8*** (4.01)	0.2 (0.05)	3.8 (1.09)	3.5 (0.72)
Married	4.0 (1.53)	4.2 (1.44)	2.9 (0.8)	0.2 (0.04)
Hhsize	0.4 (0.16)	3.5 (1.23)	−0.4 (−0.1)	−2.4 (−0.49)
Fafh	2.8 (1.18)	0 (0.00)	−3.3 (−0.89)	−3.1 (−0.59)
Educ				
Middle	2.1 (0.85)	−0.1 (−0.03)	1.4 (0.41)	3.4 (0.69)
High or technical	8.4*** (3.22)	−2.6 (−0.86)	−1.5 (−0.38)	0 (0.00)
University or higher	−5.2** (−2.35)	−0.1 (−0.07)	−1.9 (−0.58)	−1.3 (−0.35)
Phyact				
Moderate	−4.6* (−1.78)	7.3** (2.48)	3.7 (1.01)	0.2 (0.05)
Heavy	3.8 (1.58)	−2.5 (−0.91)	−1.3 (−0.46)	−0.6 (−0.18)
Year				
2004	3.3 (1.53)	3.8 (1.35)	−2.6 (−0.72)	0.9 (0.20)
2006	−2.1 (−0.8)	3.2 (1.12)	2.6 (0.74)	1.1 (0.23)
2009	0.1 (0.05)	−1.3 (−0.45)	2.9 (0.88)	−1.3 (−0.25)
2011	1.4 (0.54)	−1 (−0.35)	0.1 (0.04)	0.1 (0.02)
Pseudo R^2	0.023	0.003	0.002	0.001
LR χ^2	211.84	17.13	6.98	3.27

Note(s): Matching quality is from nearest neighbor matching with five partners. Matching quality with other algorithm produces close results. We created the treated and control groups based on the level of urbanicity index – we divided the sample into five urban quintiles. Q(1)–Q(4) refer to the quintiles; *T*-statistics are in the parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table A6. Tests of matching quality

Appendix 2

B1 Interpretation for changes in urbanicity index

$$\ln \text{energy} = 20.68 - 3.758 \ln \text{index} - 1.342 \ln h\text{hinc} + 0.346 (\ln \text{index} * \ln h\text{hinc})$$

$$\Delta \ln \text{energy} / \Delta \ln \text{index} = -3.758 + 0.346 \ln h\text{hinc}$$

When the average ln $h$hinc is 10.82, Δln energy/Δln index = −3.758 + 0.346 * 10.82 = −0.01428

Threshold level: ln $h$hinc = 3.758 / 0.346 = 10.86

When ln $h$hinc is less than 10.86, the marginal effect of urbanicity is negative.

When ln $h$hinc is higher than 10.86, the marginal effect of urbanicity is positive.

We take its antilog, Exp (10.86) = CNY 52,052.08

B2 interpretation for changes in per capita household income

$$\ln \text{energy} = 20.68 - 3.758 \ln \text{index} - 1.342 \ln h\text{hinc} + 0.346 (\ln \text{index} * \ln h\text{hinc})$$

$$\Delta \ln \text{energy} / \Delta \ln h\text{hinc} = -1.342 + 0.346 \ln \text{index}$$

When average ln index is 4.11, Δln energy/Δln $h$hinc = −1.342 + 0.346 * 4.11 = 0.08

Threshold level: ln index = 1.342 / 0.346 = 3.879

When ln index is less than 3.879, the marginal effect of income is negative.

When ln index is higher than 3.879, the marginal effect of income is positive.

We take its antilog, Exp (3.879) = 48.38.

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