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Research Article

Increasing Food Accessibility is Positively Associated with the Raising Dietary Diversity in China

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Abbreviations China Health and Nutrition Survey (CHNS); Count Index (Count); Dietary Diversity Score (DDS); Diet Quality Index-International (DQI-I); Entropy (Entropy); Simpson Index (Simpson)

Abstract

China has been undergoing a dramatic transition in food consumption since a few decades ago. The composition of diet has changed significantly. We assessed the trend of dietary diversity in China with four indicators. Count Index (Count), Dietary Diversity Score (DDS), Entropy (Entropy) and Simpson Index (Simpson) were adopted to measure the dietary diversity of 24542 adults (>17 years) through the data of 4 rounds (2004, 2006, 2009, 2011) of China Health and Nutrition Survey (CHNS). Results indicated that dietary diversity increased over time, and it was unequally distributed among different regions and families. Further investigation found that it was positively associated with accessibility of food ($p<0.01$) and other social-economic factors such as family income, household size, gender, age, education and region.

Introduction

Numerous literatures claimed that China is experiencing a nutrition transition: consumers' diet is shifting from low-fat traditional food, mainly composed of complex carbohydrates and vegetable fibers with few animal products, to a western-styled one which is high in saturated fats, sugar and proteins but low in fibers [1-9]. This shift significantly improved nutritional conditions of the poor people [8], but at the same time raised great concerns over excessive nutrition intake among rich people, given the rapid increase of overweight population in the past decades [9-11]. As a result, healthy diet attracted rising attention from both the public and the academic [10,12].

Nutritionist generally believed that healthy diets are the most diverse ones since essential nutrients cannot be drawn from a single type of food, but usually exist in different food resources [13]. Current literatures have already revealed that diverse diets can protect people against chronic diseases [14], reduce the risk of being in lack or excess of any single nutrient [15], and improve the utility of consumers by better matching between their tastes and food characteristics, or counteracting diminishing returns to quantity [16]. Therefore, dietary diversity could be used as a proxy to measure dietary quality and nutritional conditions [17], and a number of studies had developed several indicators to describe it [18-25]. On the other hand, greater food variety might also promote excess energy intake and further increase obesity since it can stimulate appetite and increase food consumption by increasing the enjoyability of meal [26-28]. The diminishing marginal utility indicates that the enjoyability of eating the same food will decrease as the quantity increases. However, when people have more diverse food, they can consume lower quantity on each food item by substituting with similar food items. Therefore, the enjoyability of eating each food items remains high, which can stimulate appetite and increase total food consumption.

The increasing variety of food can be attributed to various factors such as on-farm production diversity, increasing market access and decreasing transaction cost due to searching, shopping, traveling as well as the effect of bulk-discounting [9,16,29]. Urban citizens generally had higher accessibility of food than their rural counterparts, owing to more centralized food facilities in their residential areas, such as supermarkets, food markets, and restaurants. Rich people might also have more diverse diets since they had more abundant budget. A comprehensive investigation on dietary diversity is critical to deepen our understanding on the undergoing nutrition transition in China. We thus adopt several widely used indicators to capture the trend of dietary diversity among different regions in China. Further investigation on the associations between dietary diversity and the accessibility of food as well as other factors is also conducted to explain the heterogeneity in dietary diversity.

Materials and Methods

Sample

We adopted the data of 4 rounds of CHNS (2004, 2006, 2009 and 2011) in this study. This survey was conducted by the University of North Carolina at Chapel Hill (UNC-CH) and the Chinese Institute of Nutrition and Food Safety (INFS), China Center for Disease Control and Prevention (CCDC). The sample was drawn from 9 provinces[1] (They are Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong). (three autonomous cities, Beijing, Shanghai and Chongqing was added in 2011 survey), using a multi-stage, random-cluster process. Details about the design and the sampling of CHNS are available elsewhere [12]. We focused on all adults aged 18 and older in China with the research objects consisting of 45869 persons. After excluding children and samples with no consumption report on the twelve major food categories (processed food are not counted in our study) listed in *Chinese Food Composition* [30,31], we finally get 24542 samples, including 16115 rural respondents and 8427 urban citizens.

Measurement of individual food consumption

Individual food consumption data were recorded for three consecutive days for all household members. Respondents were asked to report on all the food they consumed at home and away from home in a 24-h recall. Trained field interviewers recorded the code of food, amount, types of meals and eating places on the previous day with the help of food models and pictures. Detailed information about the survey can be found elsewhere [12]. In this study, each food code is treated as the symbol of an individual food category.

Measurement of dietary diversity

Several indicators were developed to measure dietary variety. In general, they can be classified into two groups: the count measures which record the number of food items, and the distribution indices which take both the number and the distribution of food into account [9]. Here we selected two count indices and two distribution indicators to measure dietary diversity.

The first indicator adopted in our study is the count of individual food (Count), which is defined as the number of individual food based on food codes. CHNS listed 1506 individual food in 21 categories according to *China Food Composition* [30,31], of which the first 12 categories (1067 individual foods) refer to major food groups and the rest represent processed food (e.g., infant foods, cakes, fast food, beverages and condiments). Our study only focused on staples and excluded other food.

The second index used in our study is the Dietary Diversity Score (DDS) developed by Kant et al. (1993), which counts the number of food groups consumed daily. In order to estimate DDS, we follow Liu et al. [9] to further combine the original 12 major food categories into 6 broad groups (grains, vegetables, fruits, meat/poultry/seafood, dairy, and beans/eggs/nuts, and relevant details are presented in appendix B) based on similarities of nutrient composition and their functions in diet. Following the suggestion of Kant et al. [18], we further excluded food consumed less than the minimum amount (25g) to avoid giving credit for the consumption of a food group whose reported amount is too small. Therefore, the value of DDS ranges from 0 to 6, with higher value referring to more diverse diet.

The third measure is the entropy (Entropy) suggested by Theil and Finke [23]. Entropy is illustrated by a function of the consumption share w_i.

$$(1)\ Entropy = \sum_i^n w_i \log\left(\frac{1}{w_i}\right)$$

Since higher value of Entropy refers to high dietary diversity, the maximum diversity (logn) appears when consumption shares are equally distributed among different categories. The share w_i was calculated according to the weight of each food group.

The last indicator, the Simpson Index (Simpson) is commonly used in economic literatures to measure the variety. Simpson is computed as one minus the Herfindahl index, a widely used measure for market concentration.

$$(2)\ Simpson = 1 - \sum_i^n W_i^2$$

The value of Simpson varies from 0 (only one single food group is consumed) to $1-\frac{1}{n}$ (all food groups have equal share), and higher value refers to greater variety.

Food facilities

Food facilities refer to places where people can buy or eat food. It was commonly used as a mark of the accessibility of food [32,33]. Adequate food facilities will lower the cost of getting access to a variety of food. In this study we counted the total number of fast food restaurants, indoor restaurants, food stalls, food carts, bakeries, fruit shops, and supermarkets in the living quarters to measure the number of food facilities, which reflects the access to food market. The more food facilities one community has the easier access residents can get to diversified food and diet.

Income

The income variable used in this paper is the generated per capita income in the survey, by which both market and nonmarket activities were accounted for [34]. All incomes were deflated in terms of the Consumer Price Index (CPI) of 2004 for the purpose of comparison.

Data analysis

All statistical analyses were performed by using the Stata statistical software (version 11.0). The descriptors were presented to illustrate the distribution of diversity indices, gender, income, and food facilities. Moreover, a comparison between rural and urban residents was conducted on the basis of these indicators. t tests (for continuous variables) and Chi-square tests (for binary variables) were adopted in this study, with the significance level set to be 0.05. Finally, Pearson correlation coefficients were calculated to investigate the associations of diversity measurements with income and the number of food facilities. In addition, these associations were also demonstrated by figures processed with locally polynomial regression.

Results and Discussion

A numbers of studies had developed different indicators to measure dietary diversity, but only a few of them had focused on Chinese consumers. Kim, et al. presented a Diet Quality Index-International (DQI-I) to compare the dietary quality (including variety) of China with that of the U.S. and found that dietary variety was better achieved in the U.S. diet [22]. Li, et al. denoted that urban families reported significantly greater food variety than their rural

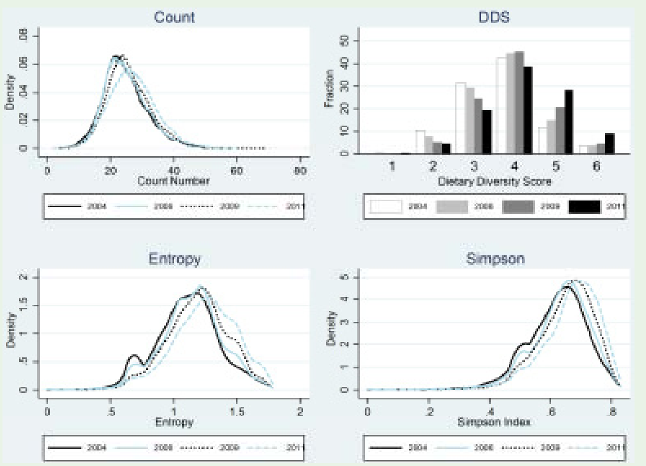

Figure 1: Trends of dietary diversity in China.
Note: Count, DDS, and Simpson refer to Count Number, Dietary Diversity Score, and Simpson Index respectively. The curves (bars) are the probability density distribution functions.

counterparts [10]. Liu, et al. investigated the impact of the accessibility of food on dietary diversity [9]. Their results showed that higher cost of food access negatively affects individuals' ability to diversify their diet. Our study went further into the topic and revealed some new phenomena.

We first presented the descriptive analysis of dietary diversity and food facility, as well as other variables in Table 1. Results showed that, on average, 25.73 kinds of food were consumed by respondents on the survey days, which belonged to 3.93 food groups. The average value of Entropy and Simpson were 1.17 and 0.64 respectively. These values were consistent with previous studies [9,10] that claimed most people had a diverse diet with one or two groups missing from their dietary record. On average, there were around 35 food facilities (including fast food and indoor restaurants, food stalls, food carts, bakeries, fruit shops, and supermarkets) in one community but with great variation (standard deviation to be 47.07). More than 40% respondents live in community with less than 10 food facilities, while one fourth respondents live in area which has access to more than 50 food facilities. Female respondents were slightly more than males (54:46) in our sample objects, and we have more rural people (66%) in our sample.

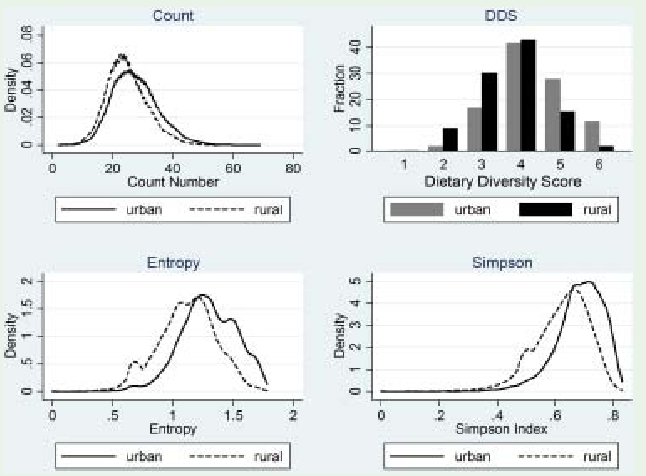

Figure 2: Distribution of four dietary diversity indices in rural and urban China.
Note: Count, DDS, and Simpson refer to Count Number, Dietary Diversity Score, and Simpson Index respectively. The curves (bars) are the probability density distribution functions.

Figure 1 showed the distribution and trend of food diversity by displaying its measurements in each year separately. All four indicators present great variations, indicating food variety varies across different people. Moreover, the distribution density curves of Count, Entropy, and Simpson all shifted to the right over time; and the DDS also concentrated on higher scores in recent years. These changes provided strong evidence of an intensifying trend of dietary diversity, indicating that food variety in China had improved during this period. In addition, we also found significant regional disparity in dietary diversity. Table 2 showed that urban residence had significantly more diverse diet than their rural counterparts in terms of all four indicators ($p<0.05$). Figure 2 displayed a clearer regional comparison by mapping up the distribution density of diversity indicators for two regions simultaneously in one graph. Compared to rural residents, urban residents were more concentrated on the right. The fraction of DDS also indicated that more urban people had highly diverse diet.

We provided strong evidence that food diversity varied across different people and time, and it was better achieved in urban China than rural China. The next step was to explore the determinants of such disparity. Current literatures have already revealed that food variety was negatively correlated with the cost of access to food [9,10,16]. Our data also uncovered a positive relationship between dietary diversity and logarithm of food facilities disclosed by all four

Table 1: Descriptive analysis of dietary diversity and other variables.

Indicators	Number	Share	mean/SD
Count			25.73(7.16)
<11	143	0.58%	
11-30	18651	75.98%	
>31	5748	23.42%	
DDS			3.93(0.97)
<3	1620	6.60%	
3-5	21540	87.76%	
6	1382	5.63%	
Entropy			1.17(0.25)
<0.8	1907	7.77%	
0.81-1.4	4701	19.15%	
>1.4	17934	73.07%	
Simpson			0.64(0.10)
<0.5	2073	8.45%	
0.5-0.7	15083	61.46%	
>0.7	7386	30.10%	
Facility			34.87(47.07)
<10	10065	41.01%	
10-50	8465	34.49%	
>50	6012	24.50%	
Income			32053(43617)
Household size			2.10(0.89)
Male			0.46(0.50)
Age			49.86(15.19)
Education			7.60(4.33)
Urban			0.34(0.47)

Abbreviations: Count: Count Number; DDS: Dietary Diversity Score; Simpson: Simpson Index; SD: Standard Deviation, which are shown in brackets.

Table 2: Comparison of dietary diversity between rural and urban China.

Variable	Rural		Urban		Comparison test	
	Mean	Std. Dev.	Mean	Std. Dev.	t/chi-square	p
Count	24.69	6.74	27.38	7.58	-28.66	<0.01
DDS	3.71	0.92	4.30	0.96	-48.75	<0.01
Entropy	1.11	0.24	1.29	0.23	-57.61	<0.01
Simpson	0.62	0.10	0.68	0.08	-53.67	<0.01

Abbreviations: Count: Count Number; DDS: Dietary Diversity Score; Simpson: Simpson Index.

Table 3: Pearson correlations between dietary diversity and income/facility.

Indicators	Facility	
	Correlations	p
Count	0.1474	<0.01
DDS	0.2105	<0.01
Entropy	0.2556	<0.01
Simpson	0.2488	<0.01

Abbreviations: Count: Count Number; DDS: Dietary Diversity Score; Simpson: Simpson Index.

indicators, which indicated that food variety will grow steadily with increasing food facilities (see Figure 3). Particularly, these curves showed an inverse trend at the end, implying that food diversity tends to decline in communities with highly massed food facilities. The Pearson correlations of diversity indices with facilities were presented in Table 3. All correlations were significantly positive (p<0.05).

To further explore the impact of increasing food facility on dietary diversity, we conducted the multivariable regression to control the effect of other variables such as income, household size, gender, age, education, regional and time differences on food variety. Results were presented in Table 4. Our regression confirmed that more food facilities were positively associated with higher food variety (all p<0.05). Specifically, 10% increase in food facilities would result in 2 more food items (Count), 0.56 more food groups (DDS), and slightly increase in Entropy and Simpson indices. Results also revealed that rich people had more diverse diet (all p<0.05), and people lived in larger household consumed more food items but their food consumption were unequally distributed, as shown by the negative association between household size and Entropy and

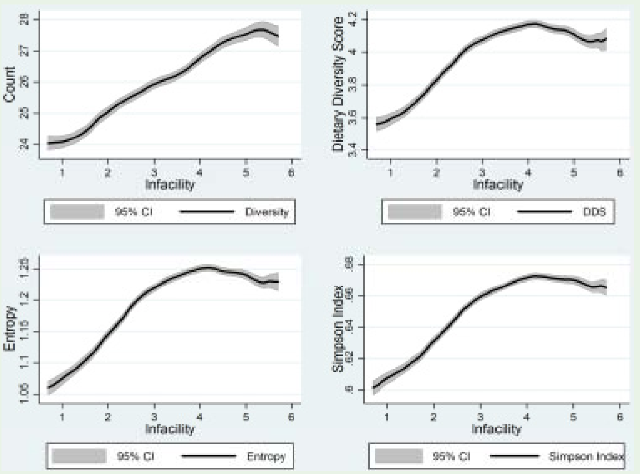

Figure 3: Association between dietary diversity and food facilities.
Note: Count, DDS, and Simpson refer to Count Number, Dietary Diversity Score, and Simpson Index respectively. The curves are the fitted lines and the grey regions are the 95% confidence intervals. Infacility refers to logarithm of facility.

Table 4: Association between dietary diversity and food facility-full sample.

Diversity	Count	DDS	Entropy	Simpson
ln(facility)	0.7983	0.1082	0.0312	0.0118
	(<0.01)	(<0.01)	(<0.01)	(<0.01)
ln(income)	0.1945	0.0562	0.0183	0.0070
	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Household size	0.6187	-0.0432	-0.0099	-0.0038
	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Male	-0.4171	-0.0985	-0.0370	-0.0130
	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Age	0.0302	0.0032	<0.011	<0.014
	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Education	0.2640	0.0441	0.0119	0.0041
	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Urban	1.1430	0.2909	0.0883	0.0303
	(<0.01)	(<0.01)	(<0.01)	(<0.01)
y2006	0.1944	0.0954	0.0314	0.0114
	(0.224)	(<0.01)	(<0.01)	(<0.01)
y2009	0.8030	0.2465	0.0742	0.0269
	(<0.01)	(<0.01)	(<0.01)	(<0.01)
y2011	1.4001	0.3083	0.0772	0.0236
	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Provincial dummy	Yes	Yes	Yes	Yes
Constant	12.0958	1.9460	0.6264	0.4427
	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Observations	24542	24542	24542	24542
p	(<0.01)	(<0.01)	(<0.01)	(<0.01)
F test	160.96	230.68	323.90	272.31
R^2-adjusted	0.2013	0.2478	0.3124	0.2751

Note: p value in brackets; ln( ) refers to the logarithm of the variables in brackets; y2006, y2009, y2011 refer to year dummy variable.

Simpson. Moreover, female, old people, well-educated people and urban residents were associated with higher dietary diversity.

As a sensitivity analysis, we also conducted the multivariable regression separately for urban and rural areas. Results were presented in Table 5. We found that rural sample disclosed very similar results with full sample, that more food facilities was positively associated with higher diverse diet (all p<0.05), and the marginal effects were even greater. However, we did not find significant relationship between food facility and dietary diversity for urban area. One possible reason is that urban area has more advanced infrastructure and the cost of access to food is much lower, so that urban residents' food purchasing and consumption might not limited in their living community. We thus substituted the community food facility with the total food facility in the whole city and re-conducted the regression in urban area (see right part of Table 5). Results showed that food facility had positive impact on food variety.

Nevertheless, our data confirmed that people lived in communities with higher density of restaurants and other food facilities had more diverse diet than other people (p<0.05, see Table 2). We thus concluded that higher access to food contributed to the increasing food diversity in China.

As aforementioned, higher dietary diversity might promote excess energy intake which might increase obesity. We thus further investigate the impact of food diversity on BMI by mapping their association in the figures (appendix A). In general, we find that increasing food diversity is positively associated with higher BMI, particularly when BMI is lower than 25.

Our study contributed to current literatures by providing a comprehensive description of food diversity in China. One major strength is that we adopted several different indicators to measure dietary diversity over a long time period in both rural and urban areas, and thus we revealed the trend of food diversity and its regional differences. We presented some evidence to prove that dietary diversity is positively associated with the number of food facilities nearby, and argued that the increasing food diversity might be attributed to higher food accessibility. Therefore, the implication of

Table 5: Association between dietary diversity and food facility-Rural and urban.

Region	Rural				Urban				Urban using city restaurants			
Diversity	Count	DDS	Entropy	Simpson	Count	DDS	Entropy	Simpson	Count	DDS	Entropy	Simpson
ln(facility)	0.7208	0.1102	0.0332	0.0129	0.9017	0.0963	0.0256	0.0092	0.8890	0.0936	0.0249	0.0089
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
ln(income)	0.3675	0.0826	0.0258	0.0097	-0.1362	-0.0112	-0.0022	-<0.015	0.0040	<0.019	<0.012	<0.011
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(0.086)	(0.200)	(0.305)	(0.495)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Household size	0.7102	-0.0224	-0.0059	-0.0027	0.3763	-0.0904	-0.0193	-0.0066	0.3505	-0.0961	-0.0209	-0.0071
	(<0.01)	(0.040)	(0.042)	(0.031)	(0.008)	(<0.01)	(<0.01)	(<0.01)	(0.012)	(<0.01)	(<0.01)	(<0.01)
Male	-0.2767	-0.0638	-0.0296	-0.0112	-0.6270	-0.1512	-0.0475	-0.0157	-0.6016	-0.1458	-0.0461	-0.0152
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Age	0.0144	0.0011	<0.016	<0.012	0.0532	0.0057	0.0017	<0.016	0.0490	0.0048	0.0015	<0.015
	(0.001)	(0.060)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Education	0.2178	0.0371	0.0104	0.0038	0.3186	0.0499	0.0128	0.0043	0.3011	0.0463	0.0119	0.0039
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
y2006	0.3491	0.1234	0.0380	0.0138	-0.2330	0.0153	0.0117	0.0044	-0.0877	0.0445	0.0194	0.0070
	(0.065)	(<0.01)	(<0.01)	(<0.01)	(0.431)	(0.669)	(0.171)	(0.154)	(0.768)	(0.214)	(0.023)	(0.027)
y2009	1.2322	0.3141	0.0925	0.0338	-0.0885	0.1044	0.0355	0.0122	0.0407	0.1297	0.0422	0.0144
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(0.771)	(0.003)	(<0.01)	(<0.01)	(0.893)	(<0.01)	(<0.01)	(<0.01)
y2011	2.0878	0.3830	0.0996	0.0323	0.0794	0.1597	0.0314	0.0051	0.1899	0.1819	0.0372	0.0070
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(0.791)	(<0.01)	(<0.01)	(0.110)	(0.526)	(<0.01)	(<0.01)	(0.028)
Provincial dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	12.4683	1.9284	0.6144	0.4352	13.7882	2.6311	0.8467	0.5275	12.6224	2.4225	0.7927	0.5102
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Observations.	16115	16115	16115	16115	8427	8427	8427	8427	8427	8427	8427	8427
p	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
F test	100.81	108.79	156.92	137.28	55.53	74.44	96.85	79.27	55.03	77.96	101.45	82.20
R^2-adjusted	0.1803	0.1785	0.2376	0.2153	0.1841	0.2083	0.2482	0.2151	0.1864	0.2180	0.2605	0.2255

Note: p value in brackets; ln( ) refers to the logarithm of the variables in brackets; y2006, y2009, y2011 refer to year dummy variable

policy making can be drawn like that: lower food diversity in remote area can be alleviated by enhancing infrastructure investment in food sectors to improve food accessibility. However, this conclusion was not based on a thoroughgoing investigation and our future research should probe into the causality between these variables.

Conclusions

As the primary finding of this study, we demonstrated that food diversity in China has got improved over time in the past decade, but there is a significant variation across different people. Our further investigation indicated that such disparity might be attributed to broader access to food facilities in some regions, as well as higher income and personal characteristics.

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