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The Effects of Adult Offspring Migration on Nutrient Intake of Rural Elderly People in China

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Abstract

Sufficient and Reasonable nutrient intake is essential for guaranteeing elderly people's health, especially in rural China where elderly people are the main labor inputs in agricultural sector. Using the 2011 wave data of China Health and Nutrition Survey, this study has empirically analyzed the impact of adult children's migration on nutrient intake of their elderly parents in rural areas. The results show that dietary energy and protein intake of rural elderly parents are inadequate where it is less than the Chinese RNI value significantly. Adult offspring migration positively relates with rural elderly parents' protein intake as well as the dietary energy intake. In the families that partly adult offspring have out-migrated or in the one-child families, elderly parents benefit more from children migration. And for male, younger and low education elders, their nutrient intake is more likely to be improved by offspring migration.

Keywords

Nutrient Intake, Adult offspring Migration, Elderly Parents, Rural China

Introduction

China has stepped into the era of rapid population aging, where the proportion of people aged 65 and over has increased from 8.87% in 2010 to 13.50% in 2020. In rural areas, since the majority of the young adults have out-migrated to work in cities or take on off-farm jobs, the aging degree is more serious than it in urban areas.¹ At the same time, due to the "separation of family members" mode of migration in China, elderly parents are usually left behind and should stay at home to take care their family and responsible for the household agricultural production.² The elderlies have become the main labor inputs in agricultural sector in China and Chinese agriculture was therefore named as the "elderly agriculture".^{3,4} Because agricultural production is labor-intensive activity and requires high-level physical inputs, Chinese rural elderly people are facing more health risks than their urban counterparts. However, the public pension system has not been sound yet in rural China, elderly care still depends more on the family supports of the adult offspring in rural areas, especially for those living with their adult offspring together.⁵ Adult offspring migration would sharply weaken these family supports and cause this traditional family elderly care system not to work effectively. Then this may further aggravate the health risks and vulnerability of rural left-behind elderly parents.² Some studies have investigated the effects of adult offspring migration on the health of their elderly parents.^{6,7,8} In China, these are even the facts.^{7,9,10,11,12,13} Generally, the existing literatures adopted self-report health status, physical health (such as illness, physical ability level), mental health (such as life satisfaction, depression, cognition) and BMI to denote individual's health and

then explore the influence of adult children migration on the health of their elderly parents. However, as the key input for producing health, nutrient intake is the material basis of guaranteeing health of elderly people, very less studies have discussed it. Motivated out of this weakness, this study has focused on the relationship between adult offspring migration and elderly people's nutrient intake. Moreover, the existing literatures only considered the fact that whether adult offspring have migrated or not, but do not pay attentions to the heterogeneity of adult offspring migration in the family like all or some adult offspring have migrated, etc. Hence this study has also inquired this relationship heterogeneity owing to the different demographical structure in the families.

In terms of these two points, this paper has used the 2011 wave data of China Nutrition and Health Survey (CHNS) to investigate the effects of adult offspring's migration on elderly parents' nutrient intake and provided answers to the following questions: how is the nutrient intake status of rural elderly in China and whether there is a significant difference between the left-behind elderly parents and the non-left-behind elderly parents? Would adult offspring's migration worsen or improve the nutrient intake of rural elderly parents? Whether the heterogeneity of migration exists due to the differences of household and individual characteristics?

The remainder of this paper is organized as follows. Literature reviews and the conceptual framework describing the link between offspring migration and nutrient intake of rural elders are provided in Section 2. Estimation method, variables' definition and data description are presented in Section 3. Then, the empirical results are listed in Section 4. The Section 5 concludes the results and suggests some policy implications.

Literature Reviews and Conceptual Framework

Labor migration is widespread in developing world, and many studies have demonstrated that migration is closely related to the health of left-behind household members.^{6,8,14,15} But, their findings show that there are contradictory results of how migration affects young children and elderly members, that some are positive related and others are negative related.^{15,16,17} In China, due to the household registration system (Hukou), most studies have focused on the effects of rural-urban migration and even provided strong evidences of these inconsistent results among young children and elderly people.^{12,18,19,20} Concluding the existing studies, most of them focused on the young children but less on the adult elders, and most of them pay attentions to the individual's physical and psychological health but less to the individual's food consumption and nutrition.

Although health is an important indicator for individuals' welfare, it depends more on nutrition and nutrients intake. For elderly people, nutrition is especially important, is a vital factor of health.²¹ As we know, malnutrition is very common in older.^{22,23,24} In China, the prevalence of inadequate intake of nutrients is considerably higher among elderly people, especially for those rural elders.^{25,26,27} However, analyzing the impact of labor migration on nutrition of rural elders is scarcely.¹³

Even migration can affect the nutrition of left-behind family members through a multiple channels,²⁸ this effect in the present studies can be divided into two parts regularly: the negative care-loss effect, that is, the labor migrants would spend less time taking care of their family members and the positive income-increasing effect, which means the migrants would transfer their income to their family, therefore the food consumption budget would be enlarged and then reduce their food insecurity.^{29,30,31} And the overall effect is mixed with these opposite effects.

Therefore, the effect of adult offspring migration on elders' nutrients intake is supposed as ambiguous in this study.

Furthermore, under the traditional Confucian culture, which is deeply rooted in rural areas, family care is dominant to the elders' care in rural China, and the intergenerational supports from adult offspring are essential for elderly people's food consumption and health. And in accordance with customary customs, the adult offspring who live with their parents together have the responsibility to take care their parents, while the offspring who have separated from their parents as a results of marriage or economic independent don't need to take on this duty. This suggests that the migrant offspring effect on nutrition is mainly manifested in those household that elderly parents live together with their adult offspring and the effect of adult offspring migration may diversify with the number of migrant labor in the family. For those parents that all of their living together adult offspring have out-migrated, the negative effect of labor loss may be larger than those that part of their living together adult offspring have out-migrated, while the positive effect of migrant offspring may be smaller. Simultaneously, this effect variation also happens between the one-child family and multi-children family. Thereby, we assume the effect of migration on elders' nutrition is varied with household characteristics.

In the meantime, the individual characteristic of elders may also affect the support of adult offspring. Generally, in the current China, the male elders in rural family should undertake more on agricultural production, while female elders are more engaged in housework or caring for grandchildren. And due to this role differentiation of males and females in the family, we firstly consider that the offspring migration effect on nutrition is varied with gender of elders.

Moreover, the age of elders may also relate with the effect heterogeneity. For those elderly parents who are relatively young, they have more work capacity and could earn income through on/off-farm employment to achieve self-caring. But for those elders that are relatively old, their

work ability has deteriorated so they mainly depend on the offspring's support to live. Therefore, the nutrition of latter may be affected significantly by offspring migration than the former. Besides of these, the existing studies have found that migration may enhance the migrant household's knowledge of health and nutrition and then potentially shift the elders' nutritional habits. But we consider the incidence of this shifting depends on the elders' education degree. The older people who have high education are expected to improve their health and dietary information from migrants. Hence, we even compare the effect heterogeneity by elders' education.

Coincide with the theoretical framework, we firstly explore the overall effect of adult offspring migration on their elderly parents' nutrition and then examine the effect heterogeneity by household and individual characteristics.

Data and empirical framework

Empirical model

To evaluate the effects of adult offspring's migration on the nutrient intake of rural elderly parents, we develop a benchmark multivariate OLS model as follows:

$$Y_i = \alpha + \beta ifchildout_i + \gamma X_i + \varepsilon_i \quad (\text{Equ.1})$$

where i denotes the i -th household. Y_i is the absolute nutrient intake of the rural elderly; $ifchildout_i$ is a dummy variable indicating whether adult offspring have migrated to city in a family; X_i represents a vector of covariates; α , β and γ are the coefficients to be estimated; ε is the error term.

In the nutrition theories, malnutrition refers to deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients, where it means not only an adequate quantity requirement for

nutrients but also an appropriate structure for nutrients.³² Therefore, a high level of absolute nutrient intake does not mean a reasonable intake. And the needs of nutrients are varied with people's physiological characteristics like age, gender. So the absolute nutrient intake should be standardized to eliminate the gender and age variation of elderly people's nutrition needs. Then, like the treating in Tian (2018), Xu et al. (2019),^{33,34} we have calculated a relative level of nutrient intake by comparing the absolute nutrient intake with the Chinese recommended nutrient intake (RNI) based on age and gender groups and used it as the independent variable to re-estimate Equ.1. Moreover, based on the deviation degree of absolute nutrient intake to RNI values, we also divide this relative intake into three categories of nutrition status: intake inadequate, intake reasonable and intake excess. Owing to an ordinal outcome, we use an ordered Probit model to estimate:

$$Y_i = F(\beta ifchildout_i + \gamma X_i + \varepsilon_i) \quad (\text{Equ.2})$$

Where $F(\cdot)$ is a nonlinear function which is set as follows:

$$F(Y_i^*) = \begin{cases} 1, & Y_i^* < \mu_1 \\ 2, & \mu_1 < Y_i^* < \mu_2 \\ \dots & \\ J, & Y_i^* > \mu_{J-1} \end{cases} \quad (\text{Equ.3})$$

Where, μ_1 and μ_{J-1} are cut points, and satisfy $\mu_1 < \mu_2 < \dots < \mu_{J-1}$. Y_i^* is the latent outcome variable defined as:

$$Y_i^* = \beta ifchildout_i + \gamma X_i + \varepsilon_i \quad (\text{Equ.4})$$

Endogeneity

Even we have controlled many variables in the OLS and ordered Probit models, but adult offspring's migration is not a random decision where adult offspring in a family decide to

migrate usually is affected by the household economic conditions and the demographical characteristics of their elderly parent.¹³ And these factors equally affect nutrient intake. Then there is an endogenous problem that would lead biased results in the OLS estimation. So we adopted the propensity score matching (PSM) method to deal with and provide a robustness test. In the PSM estimation, we firstly calculated the conditional probability $P_{(x)}$ of adult offspring migration with the Logit model to construct the control group¹ and treatment group; then matching the treatment group and the control group, we estimated the differences of nutrient intake between control and treatment group and obtained the average treatment effect (ATT) of adult offspring's migration.

$$ATT = E(Y_1|ifchildout = 1, P_{(x)}) - E(Y_0|ifchildout = 0, P_{(x)}) \quad (\text{Equ.5})$$

Where, Y_1 and Y_0 represent the daily nutrient intake of the treatment group and the control group, respectively. In order to verify the robustness of the matching results, other three matching methods are used, which are k-nearest neighbor matching (1:4), caliper matching and kernel matching.

Data

The data for this study come from the China Health and Nutrition Survey (CHNS), an ongoing open cohort, international collaborative project between the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health at the Chinese Center for Disease Control and Prevention. The first wave of this survey was conducted in 1989 and then surveyed repeatedly every two or three years. Until now, it has 10

¹ The characteristic of control group is very similar with treatment group but adult children choose to stay at home in control group and migrate in treatment group.

waves in 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011 and 2015 that could be available openly². Since the latest dietary survey in the CHNS is up to 2011 and the balance panel data would lose a large number of samples, this study was only analyzed with the 2011 wave data. Moreover, due to the topic of this study, we just keep the sample households in the rural site³ that have elderly people whose age is 60 years old and above. In the meanwhile, to meet the sample consistency principle in econometric analysis, we limit the samples on those rural elders that have adult offspring living together. After dropping the households with missing values on dependent and independent variables and households where parents have not adult offspring or adult offspring are not living together, 1487 observers are used in the empirical analyzing.

Variables and Sample description

We use the absolute level of daily dietary energy intake and protein intake to denote the nutrient intake firstly, where the dietary energy intake indicates the quantity of nutrient intake and the protein intake indicates the quality of nutrient intake. Based on the food consumption records in CHNS, this absolute value is a three-day average value. The relative nutrient intake is a ratio value that is calculated by energy (protein) intake / RNI by age and gender groups⁴. And this relative has been grouped into three categories. When its value is between 0.95 and 1.05, it indicates the nutrient intake is reasonable and has value 2; and when this ratio value is lower than

² The 10 waves of the survey covered 15 provinces: Beijing, Chongqing, Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Liaoning, Jiangsu, Shaanxi, Shandong, Shanghai, Yunnan and Zhejiang. The 2011 data used in this article cover 10 provinces, including Beijing, Chongqing, Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Liaoning, Jiangsu, Shandong and Shanghai.

³ Since a large proportion of households missed *Hukou* information, we identified rural families by their survey location.

⁴ In the RNI, the average daily total energy intake of male elderly 60 years old and older is 1900 kcal, 1800 kcal and 1700 kcal is for female elderly 60-70 years old and over 70 years old respectively; the average daily protein intake of male elderly 60 years old and older is 75g, and 65g for female elderly 60 years old and older.

0.95 or greater than 1.05, it indicates the nutrient intake is inadequate or excess and has value 1 or 3.

Considering the convention that elderly people in rural China are cared by their adult offspring living together, we define parents left-behind in line with whether their adult offspring living together have migrated to city in this study. Therefore, the dummy variable of adult offspring's migration is merely defined as the migration of adult offspring living together. If adult offspring in the family has migrated, this variable's value is 1, otherwise it is 0. In this data, 465 elderly parents have migrant adult offspring, accounting for 31.27% of the total sample, and 1022 elderly parents have not migrant adult offspring, accounting for 68.73%.

The control variables contained in the regression model are sex, age, education degree, health status, medical insurance, healthy dietary knowledge, cigarette smoking, alcohol drinking and grandchildren care of elderly parents, household assets, household size and regional dummy variable. The variables definition and sample description are listed in Table 1.

Table 1 - Variables definition and sample description

Variable	Definition	Parents without migrated children		Parents with migrated children		Full sample	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
sex	elderly parent's sex: 1=male, 0=female	0.447	0.497	0.475	0.500	0.456	0.498
age	elderly parent's age	68.86	7.114	67.12	6.333	68.316	6.924
edu	elderly parent's educational year	4.338	3.951	3.955	3.489	4.218	3.816
ill	whether elderly parent has illness: 1=yes, 0=no	0.231	0.422	0.202	0.402	0.222	0.416
insur	whether elderly parent has medical insurance: 1=yes; 0=no	0.977	0.152	0.976	0.152	0.976	0.152
guide	whether elderly parent know Chinese dietary guideline: 1=yes; 0=no	0.131	0.338	0.151	0.358	0.137	0.344
smoke	whether elderly parent smokes cigarette: 1=yes; 0=no	0.261	0.44	0.269	0.444	0.264	0.441
drink	whether elderly parent still drink alcohol: 1=yes; 0=no	0.222	0.416	0.234	0.424	0.226	0.418

childcare	whether elderly parent take care grandchildren: 1=yes; 0=no	0.11	0.313	0.166	0.372	0.127	0.333
hhsz	household size	3.44	1.777	5.201	1.768	3.988	1.952
asset	household assets that indicated by the quantity of household electrical appliances	10.254	6.172	9.967	5.64	10.164	6.01
region	regional dummy variable: 1=northeastern and eastern; 0=other regions	0.427	0.495	0.232	0.423	0.366	0.482

Estimation Results and Discussions

Nutrient intake of elderly parents

Table 2 reports the statistical results of dietary energy intake and protein intake of elderly parents in rural China. We can see from this table that the average daily dietary energy intake of the full sample is 1856.06 kcal, which is lower than the minimum energy intake of 1900 kcal for light physical workers who aged over 60 years old. And in the group that parents without migrant adult offspring, the dietary energy intake per day is 1795.17 kcal, while it is 1989.89 kcal in the group with migrant children. The T-test statistics of these two groups' difference is significant at the 1% level, which means there is a notable inter-group difference that elderly parents with migrant adult offspring have got more energy than parents without. The daily protein intake of full sample is 57.36 g. And in the group without migrant children, it is 55.87 g, which is significantly lower than it (60.63 g) in the group with migrant children. The daily protein intake in all groups is less than the recommended level that male is 75 g/per day and female is 65 g/per day.

Table 2 - Absolute nutrient intake of the rural elderly parents

nutrient intake	Without migrant children		With migrant children		Difference	full sample	
	Mean	S.D.	Mean	S.D.		Mean	S.D.
Dietary energy intake	1795.17	596.38	1989.89	631.18	194.73***	1856.06	600.67

(kcal/per day)							
protein intake quantity	55.87	20.63	60.63	22.46	19.04***	57.36	21.33
(g/per day)							

Table 3 further reports the results of standardized nutrient intake where it is calculated by absolute intake/RNI. On the whole, the standardized intake of energy and protein of rural elderly parents are 0.954 and 0.775, which both statistically significant less than the RNI value at the 1% significance level. And this indicates they are inadequate for physical needs. However, if observing these from the parents with and without migrant adult offspring, we found the dietary energy and protein intake of parents without migrant children are hard to satisfy the body's nutrient needs, but the dietary energy intake could meet with the physical needs in group with migrant children and protein do not meet. And the T test of inter-group difference also shows the standardized nutrient intake of parents with migrant children is better than their counterpart.

Table 3- Standardized nutrient intake of rural elderly parents

nutrient intake	Without migrant children		With migrant children		Difference	Full sample	
	Mean	S.D.	Mean	S.D.		Mean	S.D.
dietary energy intake ratio	0.921***	0.386	1.025	0.406	0.103***	0.954***	0.395
protein intake ratio	0.754***	0.347	0.821***	0.362	0.067***	0.775***	0.353

The effects of adult offspring migration on nutrient intake of elderly parents

Baseline results

The baseline outcomes are listed in Table 4. On the absolute level, the OLS estimates show that adult offspring's migration has strong positive effects on rural elders' dietary energy and protein intake. The coefficients of adult offspring's migration indicate the elderly parents in households with migrant adult offspring would intake more energy of 183.737 kcal and more protein of

19.614 g than those in the households without migrant adult offspring. On the relative level that have eliminated the age and gender impacts on nutrition requirements, these positive effects are equally significant and it has a 0.101 increments for energy and 0.070 increments for protein. These have also been confirmed with the results of ordered Probit model. And all these results indicate adult offspring's migration could improve the quality of nutrient intake of elderly parents as well as the quantity. Because, in the present rural China, the off-farm wage income due to rural-urban migration has become the major source of household income, adult offspring's migration is very helpful to increase household income and then could significantly improve their left-behind parents' food consumption and therefore their nutrient intake. And from these results, we believe that adult offspring's migration could enhance the nutrition status of left-behind elderly adults in terms of quantity and quality, and further positive contribution to elders' health and welfare.

In additional to adult offspring's migration, elderly people's gender, age, illness status, healthy dietary knowledge, medical insurance, alcohol drinking are strongly related with their absolute and relative dietary energy intake. And elderly people's age, illness status, medical insurance, alcohol drinking, family care of grandchildren and household assets are strongly related with their absolute and relative protein intake. From their estimated coefficients, we can conclude that the energy intake of female, older and illness parents is lower than that of male, younger and healthy parents. These possibly mean that female, older and sick elderly parents are not taken seriously in rural families and then have high probability trapping into an inadequate status of nutrition. Medical insurance whatever the public or commercial insurance is helpful to elderly parents to have more energy intake, and this is mainly because medical insurance could reduce the preventative saving and medical cost of elderly parents and then make them have more food expenditure.³⁵ Knowing the Chinese dietary guideline means the elderly parents owing more

health dietary awareness and knowledge, which resulting them in more energy intake. The elderly parents who drink alcohol have a higher energy intake. In terms of protein intake, the effects of age, illness, medical insurance and alcohol drinking are similar to their effects in energy intake estimation. If parents should take care of grandchildren, they would have more less protein intake obviously. This is mainly because rural elderly parents prefer to leave more foods with high nutrient content to grandchildren, so their protein intake is reduced. Family assets have significant positive influences on protein intake of rural elderly parents. This is mainly because rural elderly parents in families with better economic conditions have a wider food selection scope and prefer foods with higher nutrients.

Table 4 - Adult offspring's migration and nutrient intake of elderly parents

Variables	absolute level (OLS)		relative level (OLS)		relative level(Ordered Probit)	
	energy	protein	energy	protein	energy	protein
ifchildout	183.737*** (39.613)	19.614*** (5.883)	0.101*** (0.022)	0.070*** (0.021)	0.336*** (0.089)	0.348*** (0.095)
sex	213.828*** (42.482)	26.085*** (6.143)	0.042* (0.023)	-0.025 (0.022)	0.221** (0.092)	-0.104 (0.101)
age	-12.607*** (2.328)	-1.419*** (0.330)	-0.005*** (0.001)	-0.005*** (0.001)	-0.027*** (0.006)	-0.013** (0.006)
edu	-2.025 (4.951)	-0.065 (0.719)	-0.002 (0.003)	-4.00E-4 (0.003)	-0.013 (0.011)	-0.005 (0.012)
ill	-149.476*** (34.555)	-14.445*** (5.282)	-0.080*** (0.019)	-0.051*** (0.019)	-0.219** (0.086)	-0.229** (0.094)
insur	235.483*** (63.262)	34.511*** (11.762)	0.128*** (0.035)	0.129*** (0.043)	0.657** (0.266)	0.530 (0.337)
guide	89.455* (46.662)	7.203 (6.955)	0.050** (0.025)	0.030 (0.025)	0.139 (0.105)	0.061 (0.111)
smoke	16.751 (44.704)	-6.808 (6.335)	0.012 (0.024)	-0.022 (0.022)	0.041 (0.095)	-0.012 (0.103)
drink	138.987*** (45.130)	22.551*** (6.693)	0.077*** (0.024)	0.079*** (0.023)	0.160 (0.098)	0.297*** (0.103)
childcare	-43.172 (44.291)	-13.587** (6.261)	-0.023 (0.024)	-0.049** (0.023)	-0.078 (0.113)	-0.285** (0.122)
hhsiz	0.927 (10.388)	0.849 (1.550)	1.00E-6 (0.006)	0.003 (0.006)	-0.007 (0.024)	-0.013 (0.026)

asset	-0.193 (3.041)	1.782*** (0.435)	9.00E-05 (0.002)	0.006*** (0.002)	0.010 (0.007)	0.026*** (0.008)
region	51.791 (34.789)	19.437*** (5.244)	0.028 (0.019)	0.069*** (0.019)	0.040 (0.077)	0.239*** (0.083)
Constant	2,308.214*** (182.978)	246.959*** (27.233)	1.173*** (0.101)	0.939*** (0.099)	0.986** (0.502)	-0.602 (0.582)
F/Wald Chi2	17.17***	14.66***	10.57***	10.23***	96.18***	76.38***
R2	0.139	0.133	0.087	0.093	0.039	0.038

a Standard error is in parentheses.

b ***, ** and * represents the 1%, 5% and 10% significance level respectively.

PSM results

In PSM estimation, balance test should be applied firstly to confirm whether there are systematic differences of concomitant variables between samples without and with migrant adult offspring. After matching, absolute value of the standard deviation of all variables is smaller than 20%, and the standard deviation declines significantly (Table A1). Meanwhile, T-test value of the difference between these two groups indicates that most variables are not significant after matching, so the matching effect is good and the self-selection bias of samples can be weakened with the PSM method.

Considering there are similar effects of adult offspring's migration on nutrient intake in baseline estimation, using k-nearest-neighbor matching (k=4), caliper matching (caliper=0.05) and kernel matching respectively, we re-estimate these effects on relative intake level (Table 5). And the positive average treatment effects on treated group (ATT) in PSM estimation have supported the baseline results again. At the same time, we find that the estimated coefficient of adult offspring's migration has declined in the PSM model than it in OLS model, indicating the endogeneity from self-selection of migration could cause an overestimation of the effects of adult offspring's migration on nutrient intake of rural elderly parents. In the subsequent section, we apply PSM model to analyze the heterogeneity of migration effects.

315

Table 5 - PSM results

Matching method	energy	protein
k-nearest neighbor matching (k=4)	0.084*** (0.025)	0.057** (0.024)
caliper matching (caliper=0.05)	0.075*** (0.025)	0.050** (0.023)
kernel matching	0.074*** (0.025)	0.050** (0.023)

316 a *, ** and *** denote 10%, 5% and 1% significance levels. Standard error is in parentheses.

317 b ATT are reported.

318

319

320 **Heterogeneity analysis**

321

322 **Heterogeneity with number of migrated children**

323 In here, we compare the migration effect by the number of migrated children. In light of whether

324 all adult offspring who living together have out-migrated to the city, we divide the sample into

325 two subgroups: all adult offspring have migrated and partly adult offspring have migrated.

326 From the results shown in Table 6, we find children migration has insignificant impact on energy

327 and protein intake of rural elderly parents in the subgroup that all adult offspring have migrated,

328 while it has a notable positive impact on the subgroup that partly adult offspring have migrated.

329 Family care from adult offspring is very important for rural elderly parents in China. In the

330 families with all adult offspring have migrated, elderly parents are hardly cared from their adult

331 offspring and have low-quantity and quality of food consumption. However, in the families that

332 part of adult offspring migrated, adult offspring who stay at home could provide care and support

333 for parents and children who out-migrated for work could increase household income to improve

334 food consumption, thus parents' nutrition would benefit more from adult migration. So we

335 believe that, even migration could increase household income and then may have similar effects

on nutrient intake of elderly parents in these two subgroups, this improvement effect hardly compensates the decline effect of family care reducing.

Table 6 - Heterogeneity with number of migrated children

Matching method	All adult offspring have migrated		Partly adult offspring have migrated	
	energy	protein	energy	protein
k-nearest neighbor matching (k=4)	0.060 (0.038)	0.003 (0.036)	0.049* (0.027)	0.043* (0.024)
caliper matching(caliper=0.05)	0.056* (0.034)	0.011 (0.032)	0.070*** (0.024)	0.056** (0.023)
kernel matching	0.054 (0.034)	0.011 (0.032)	0.070*** (0.024)	0.057** (0.023)

a *, ** and *** denote 10%, 5% and 1% significance levels. Standard error is in parentheses.

b ATT are reported.

Heterogeneity with family structure

In here, the sample is grouped into two subsamples by family structure that one-child families and multi-child families. The estimated results are shown in Table 7. Children migration has a similar positive impact on energy intake of rural elderly parents in these two types of families, and this effect in one-child families is greater than it in multi-child families.

However, on protein intake, the effect of children migration in one-child families is unobvious, while it is significant in multi-child families. And also we notice this positive effect is just significant at a low statistical level.

Table 7 Heterogeneity with family structure

Matching method	One-child families		Multi-child families	
	energy	protein	energy	protein
k-nearest neighbor matching (k=4)	0.216*** (0.081)	0.121* (0.064)	0.076*** (0.028)	0.049* (0.026)
caliper matching(caliper=0.05)	0.215** (0.090)	0.106 (0.077)	0.065** (0.026)	0.043* (0.024)
kernel matching	0.219** (0.090)	0.109 (0.076)	0.065** (0.026)	0.044* (0.024)

a *, ** and *** denote 10%, 5% and 1% significance levels. Standard error is in parentheses

b ATT are reported.

Heterogeneity with individual characteristics of elders

We investigate the effect's heterogeneity on gender, education and age of rural elderly parents in this section. First, the results in Table 8 show energy intake of both male and female rural elders is positively affected by their children migration significantly, but protein intake is unaffected by migration. This means the quantity of nutrition of male and female elders is more likely improved by migration but protein. In terms of the magnitude of effect on energy intake, we find although both benefit, male elders probably benefit more than female. The likely explanation of this finding is that male adults in Chinese families especially in rural areas are superior to female. In rural China, male adults usually are the household head and main labor for on/off-farm production. To ensure family income, nutrition of male members is paid more attention than female and more likely be guaranteed firstly. Therefore, the effect of children migration is stronger in male group than female group.

Table 8 - Heterogeneity with elders' gender

Matching method	Male		Female	
	energy	protein	energy	protein
k-nearest neighbor matching (k=4)	0.087** (0.038)	0.068** (0.033)	0.069** (0.034)	0.042 (0.033)
caliper matching(caliper=0.05)	0.086** (0.037)	0.055 (0.033)	0.070** (0.033)	0.049 (0.034)
kernel matching	0.084** (0.037)	0.053 (0.033)	0.071** (0.033)	0.052 (0.034)

a *, ** and *** denote 10%, 5% and 1% significance levels. Standard error is in parentheses.

b ATT are reported.

Generally, the work capacity of elders would worsen rapidly with age growing. This lead older elders to contribute less than the younger counterpart for household production and income. Therefore, we consider, since the elders lost their work capacity due to aging, they are more

likely ignored in caring from family. In terms of this, we divide the whole samples into two groups by age: 60-70 years old and over 70 years old and then compare the migration effect by age. The estimated results in Table 9 show both energy and protein intake are positive affected by adult offspring migration significantly in the group of aged 60-70 years old. But in the group of elders aged over 70, this positive effect could only be significantly observed on the energy intake and is higher than that in 60-70 years old group. These results illustrated the quantity and quality of nutrition of rural elders whose age is 60-70 are both improved by adult offspring migration, while for the elders whose age is over 70, only the quantity of nutrition is obviously increased.

Table 9 - Heterogeneity with elders' age

Matching method	60-70 years old		Over 70 years old	
	energy	protein	energy	protein
k-nearest neighbor matching (k=4)	0.081*** (0.029)	0.058** (0.028)	0.108** (0.045)	0.068 (0.043)
caliper matching(caliper=0.05)	0.085*** (0.028)	0.060** (0.026)	0.101** (0.046)	0.068 (0.047)
kernel matching	0.085*** (0.028)	0.060** (0.026)	0.098** (0.046)	0.065 (0.047)

a *, ** and *** denote 10%, 5% and 1% significance levels. Standard error is in parentheses.

b ATT are reported.

Education is an important determinate of personal healthy knowledge (Liu et.al., 2017) and so it may influence the migration effect on rural elders' dietary intake structure and nutrition. The estimated results are listed in Table 10. According to the education distribution of rural elders, we split the entire samples into low level group whose educational level is less than primary school diploma and high level group whose education level is above primary school diploma group. As we can see from Table 10, the effect of offspring migration is significant both on the energy and protein intake in the low educational level group, but it is insignificant in higher level

group. These results suggest that, for less-educated elders in rural families, offspring migration could not only improve their nutrient quantity but also their nutrient quality. For its reason, we consider it may be related with the relative high level of healthy awareness and dietary knowledge of rural more-educated elders and they pay more attention to their health and balanced diet in daily life. Therefore, adult offspring's migration hardly has obvious effects on their nutrient intake.

Table 10 Heterogeneity with elders' educational level

Matching method	Low level		High level	
	energy	protein	energy	protein
k-nearest neighbor matching (k=4)	0.097*** (0.029)	0.073*** (0.026)	0.043 (0.055)	0.004 (0.059)
caliper matching(caliper=0.05)	0.104*** (0.027)	0.074*** (0.026)	0.035 (0.050)	0.008 (0.052)
kernel matching	0.104*** (0.027)	0.074*** (0.026)	0.037 (0.050)	0.005 (0.051)

a *, ** and *** denote 10%, 5% and 1% significance levels. Standard error is in parentheses.

b ATT are reported.

Conclusions

As a high healthy vulnerable group in China, older adults in rural areas are characterized by malnutrition. In this study, we apply PSM model to solve self-selection problem in estimation with 2011 wave of CHNS to examine the relationship between adult offspring's migration and nutrient intake of rural elderly parents and explore the effects' heterogeneity. The results show that the quantity of nutrient intake indicating by dietary energy and the quality of nutrient intake that indicated by protein of rural elderly are both less than the recommended value, mean notable insufficient intake of nutrient is widespread in the rural elderly populations. Controlling for a

413 series of factors affecting nutrient intake, a positive increasing of energy and protein intake of
414 elderly parents in families with adult offspring migration.

415 To account for the heterogeneity of elders, we compare the effects of adult offspring migration
416 by the number of migrant children, household structure, elders' gender, age and education.

417 Overall, the results for many subgroups are similar with the baseline results. Specifically, the
418 effects on dietary and protein intake in those families with partly adult offspring have migrated
419 are both notable while are both insignificant in the families that all adult offspring have migrated.

420 In one-child and multi-child families, these effects on dietary energy and protein are both
421 significant, but stronger in one-child families. In terms of gender, age, and education, energy and
422 protein intake of male elders or elders younger than 70 years old would both benefit from
423 migration, but only energy would benefit for female elders or elders aged over 70; For those
424 elders whose educational level is less than primary school, this effect on energy and protein is
425 significant, but insignificant for elders whose educational level is above primary school diploma.

426 In general, the effect of adult offspring migration on rural elders' nutrition status has been
427 investigated carefully in this paper and its findings have important implications for policy, given
428 that adequate nutrition is essential to elders' health and well-being. Despite there has a positive
429 role of offspring migration played on elderly parents' nutrient intake apparently, malnutrition of
430 rural elders remains an issue worthy of social attentions in China. More effective measures need
431 to be adopted to target this issue. Firstly, the government should enhance publicity of nutrition
432 knowledge to raise the nutrition awareness of elderly adults and carry out nutrition monitoring
433 and healthy dietary guidance for elderly people to make them realize reasonable food
434 consumption in rural areas. Secondly, the improvement of a social pension system which
435 involves the participation of family, market institutions and government together should be
436 accelerated in rural areas and then lower the pension costs to make them have more dietary

inputs. Third, a labor market with free labor mobility should be set up rapidly to guarantee more elderly parents migrated with their adult offspring.

Because of the limitations of CHNS data that does not provide detailed information of income, remittances from migrant children, the time allocation of elders and offspring supports from adult offspring have separated from their households, two shortages are shown in this study. First, although the positive effect of adult offspring migration on nutrient intake of rural elderly parents has been revealed, it is an overall effect, which includes the positive effect from transfer income of migrant children and the negative effect from less family care. And so the mechanism of this effect is hardly to explored. Second, we only discuss the impact of migration of adult offspring in those households that elderly parents and adult offspring are belonging to the same family in law. Therefore, those rural elders who do not have adult offspring or adult offspring have separated from family in law are not included in the analyzing samples and then the findings may not reflect the overall facts in some degree.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

All data generated or analysed during this study are included in this published article [and its supplementary information files].

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

JQJ、SYD and ZYL prepared the figures and tables. LL、MZ and ZHW drafted the work or revised it critically for important content.

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