Decoding the Growth-Nutrition Nexus in China: Inequality, Uncertainty and Food Insecurity

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September 2014

BWPI Working Paper 207

ISBN: 978-1-909336-25-4

Brooks World Poverty Institute

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www.bwpi.manchester.ac.uk

Abstract

Chinese households have experienced significant income growth, while their nutrition intake has not increased *pari passu*. This paper uses household data in both rural and urban China over the period 1989-2009 to explain the paradox of higher income but lower nutrition. In addition to traditional inputs into nutrition intake, we emphasise different sources of income, the heterogeneous income effects across households, and the price effects under rising and volatile food prices. The instrumental variable estimation shows that, although nutrition is not responsive to aggregate income, pro-agriculture income growth in terms of proportionally more crop income raises rural households' nutrient intake, while business and wage income improves urban households' nutrition. The estimation of a quantile instrumental variable fixed-effects panel model further documents a nutrition-improving effect of income for the least nourished and only the better-nourished are able to benefit from widely believed contributors of nutrition intake such as dietary knowledge, local off-farm employment and out-migration. Uncertainties attached to prices of meat, eggs and oil and fat accentuate nutrition poverty and can off-set the positive income effect, raising the risk of food insecurity *despite* growing income.

Keywords

food security, nutrition, inequality, poverty, IV regression, quantile regression, China

Acknowledgements

This study is sponsored by IFAD (International Fund for Agricultural Development). We are grateful to Thomas Elhaut and Constanza Nucci for their support and guidance throughout this study and for their insistence on highest standards of analytical rigour. We are grateful for valuable comments from an anonymous referee at BWPI. The views expressed are personal and not necessarily of the organisations to which we are affiliated or of IFAD.

1. Introduction

The Chinese households have experienced continuous income growth for more than three decades. Per capita disposable income increased at an annual rate of 3.4% from 1980 to 2012 for urban households, and 2.8% from 1985 to 2012 for rural households.[1] Remarkable income growth helped the income poverty headcount ratio at the US$1.25 poverty line plummet from 85.3% in 1981 to 11.8% in 2009.[2] Nevertheless, nutritional situation has not improved in parallel with income growth. Based on the nationally representative China Health and Nutrition Survey (CHNS), 2000-2006, Shimokawa (2010) finds little correlation between household wealth and nutrient intake. In both urban and rural areas, the income elasticities for food (e.g., grain and vegetables) and nutrients (e.g., calories and protein) with a low unit value are nearly zero (Gale and Huang, 2007; Bishop *et al.*, 2010) and even negative as income keeps rising (Huang and Gale, 2009), implying a satiation for food consumption for wealthy households (Zheng and Henneberry, 2010).[3] Ma *et al.* (2004) and Hovhannisyan and Gould (2011) also find that expenditure elasticities became smaller and stabilised over the period 1995-2003. As a result, malnutrition and dramatic income poverty reduction co-exist in China. This is in sharp contrast to the common wisdom and cross-country studies documenting positive impact of income growth on nutrition, as recently summarised by Headey (2013).

One explanation for this paradox pertains to the Chinese dietary transition along income growth. Household per capita consumption of fat and oil grew annually at an average of 2.7% in rural areas and 11.6% in urban areas between 2003 and 2011 (You, 2014), while lower amounts of vegetables and fruits were consumed over time. Fine grains and rice become increasingly popular instead of coarse grains (Carter and Zhong, 1999). Chinese diet has been shifting away from traditional foods with coarse grains as the staple to the westernised ones full of high carbohydrates (Du *et al.*, 2004). The CHNS data suggest that income effects on low-fat and high-fibre food, such as wheat-flour products and coarse grains, fell from 1989 to 1993, proportionally more among richer households, while income elasticities of pork, edible oil and eggs increased significantly (Guo *et al.*, 2000). Despite a number of studies documenting preferences towards a western-diet, their micro-level datasets are for either urban or rural areas, and the time period is too short to capture usually long and gradual socio-economic transitions. More importantly, there has not been direct analysis of whether the above changes in Chinese diet are associated with the decline in nutrient intake, nor its relative importance, compared to other possible contributing factors.

An alternative explanation for the income-nutrition paradox is the intensified uncertainties in households' livelihood.[4] Meng *et al.* (2009) find that income elasticities are not close to zero based on the 1986-2000 waves of the Urban Household Survey conducted annually by the National Bureau of Statistics (NBS) in all provinces. It was found in their study that the poorer the individuals were, the

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[1] Authors' calculation based on data from China Statistical Yearbook published annually by the National Bureau of Statistics (NBS) of China. The household data in it come from the nationally representative Rural Household Survey and the Urban Resident Survey conducted annually by the NBS.

[2] Figures in this and next sentences are compiled from Chen and Ravallion (2010) and Table 2.8 in the World Development Indicators 2014.

[3] Behrman and Deolalikar (1987) have also reported using the ICRISAT panel data in India in the 1970s that the true nutrient elasticities with respect to income is close to zero, although this study was criticised by Subramanian and Deaton (1996) who estimated the elasticity as 0.3-0.5 by using the Indian NSS data in 1983. An important point of departure of these studies was to focus on calorie intakes at micro level, rather than food production, to derive the nutrient elasticities.

[4] What is also important here is the effect of change in relative price effect of edible oil or sugar-sweetened beverages and their greater consumption in developing countries. Popkin *et al.* (2012) argue that in both low and middle income countries new technology of oil extraction from seeds led to lower costs and prices, which has contributed to higher intake of edible oil.

higher the income elasticities of calorie consumption became. It is the soaring food prices in the early 1990s and uncertainties, proxied by the heavy burden of education, medical and housing expenses, as a result of social welfare reforms in the mid- and late 1990s that supressed calorie consumption, especially for those in the lower end of the income distribution. In fact, increased uncertainties attached to household income and consumption streams have emerged not only in urban but also in rural China, and could bring about substantial welfare losses (You and Ozanne, 2014). To the best of our knowledge, Meng *et al.* (2009) is the only study estimating the nutritional effects of uncertainties during major social reforms, but merely for urban areas.

This paper aims to provide the first comprehensive investigation for the determinants of household nutrient intake in both urban and rural China based on the repeated nation-wide surveys for two decades (1989-2009) in order to demystify the paradox of rising income but declining nutrient intake. A point of departure of the present study in light of its unique contribution to the previous literature on the determinants of nutrition in China or in other developing countries is to model (i) heterogeneity in the effect of household income and nutritional intake as well as (ii) the endogenoity of household income. This will provide a robust estimate for the effect of income on nutrition at different levels of nutritional intake. In terms of the choice of covariates, we include not only "traditional" inputs of nutrition, but also direct proxies for uncertainties in household livelihood. Moreover, we are particularly interested in the distributional effects on nutrient intake of various inputs, indicated by heterogeneity in nutritional responses to income in the aforementioned literature. Our analysis will add to the understanding of China's experience of rising income but declining nutrition in recent years. It will thus inform government interventions in nutrition improvement and food security for not only China but also for other developing countries facing the similar dual challenge in reducing poverty and hunger at the same time.[5]

The remainder of this paper is organised as follows. The next section introduces the dataset and describes the trend in Chinese households' dietary transition and the changes in distribution of their nutritional status. Section 3 spells out the estimation strategy. Section 4 discusses econometric results and the final section provides concluding observations and policy implications.

2. Data

We use the China Health and Nutrition Survey (CHNS) conducted by the Carolina Population Center at the University of North Carolina in 1989, 1991, 1993, 1997, 2000, 2004, 2006 and 2009. The multi-stage random sampling method and broadly same questionnaires have been applied to each wave.[6] The sample provinces are spread across northeast (Liaoning and Heilongjiang), coastal (Jiangsu and Shandong), central (Henan, Hubei and Hunan), and southwest regions (Guangxi and Guizhou). There are about 4,400 households including 26,000 individuals in each wave, with a higher proportion for rural than urban households defined by their actual places of residence. We have chosen the household as a main unit of the analysis and have constructed the pooled cross-sectional data as well as the (unbalanced) panel dataset based on 8 rounds of CHNS for our empirical analyses. After excluding households with missing values on key nutrition and economic indicators, we extract 29,402 households in the pooled cross-section. The sample size for each round varies from 2,174 in 1989 to

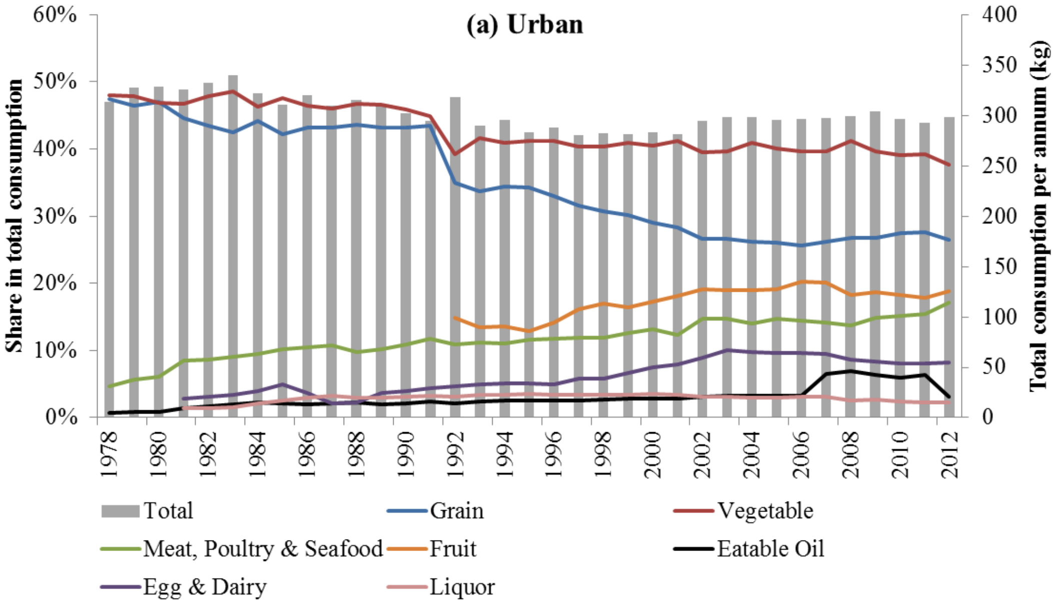
[5] FAO (2013) argues that in countries where food insecurity is more pervasive, nutrition is less associated with income. Ample food availability and the shifts in consumption and lifestyle benefiting from income increases do not necessarily enable improvement in nutrition, e.g., Nicaragua in 2005-2007.

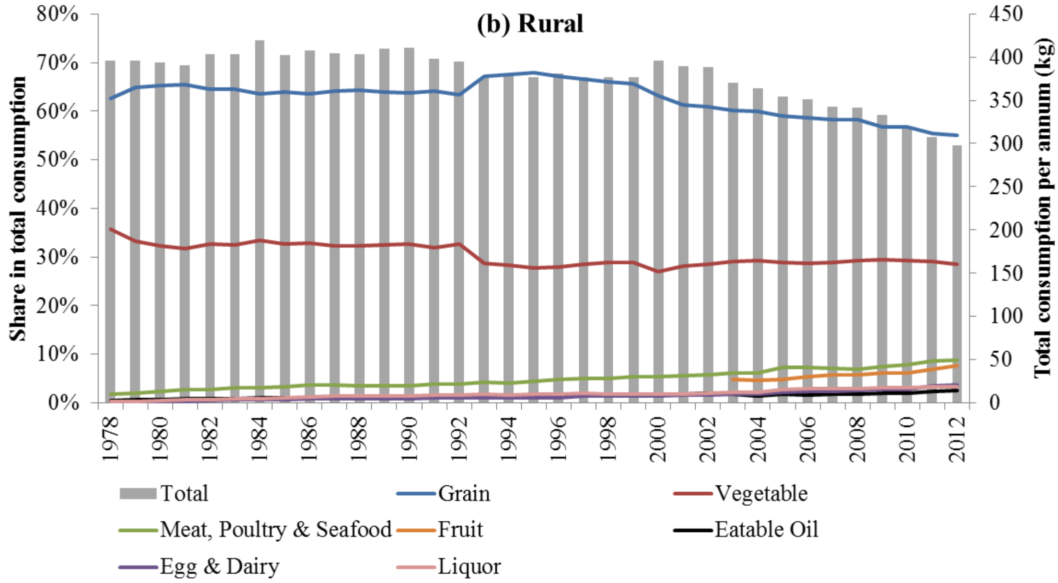
[6] Detailed information on sampling procedures can be found on the CHNS webpage: http://www.cpc.unc.edu/projects/china [accessed 8 August, 2014].

4,444 in 2009. The share of urban households varies from 29.8% (in 2000) to 39.7% (in 1989). Ethnic minorities have been covered, with the share ranging between 0.5% (in 2006) and 11.3% (in 1989). A list of all variables used for those households, including the definitions and descriptive statistics, can be found in Appendix 1.

The macro data suggest a decreasing trend in Chinese food consumption. As shown by Figure 1, the household per capita total food consumed has decreased by a quarter in rural areas and by 4.6% in urban areas since 1978. However, the timing of these changes is different between rural and urban areas: they first took place in urban areas prior to 2000, and then in rural areas thereafter. Figure 1 also demonstrates changes in dietary composition over time. There are observed significant decreases in the proportions of grain and stable consumption of vegetables except a drop in the early 1990s, while the proportions of oil, meat (including poultry and seafood), eggs, dairy, fruit and liquor have increased. Rural households mainly consume grain and vegetables, while other foods constitute little in their diet. The proportion of grain consumption has declined only since 2000, and has decreased by 8 percentage points over the period 2000-2012. On the other hand, urban households consumed vegetables most, and then grain. The proportion of the former has been relatively stable, while the proportion of the latter has been halved since 1978 and 95% of this decrease has happened since 1992 when the second wave of economic reform in coastal (urban) areas was initiated by Mr. Xiaoping Deng. Comparing rural and urban households, the former consumed more quantity of food which came from grain, while the latter consumed more vegetables, meat, and oil.

Figure 1 Household per capita annual consumption of foods (e.g. grain, vegetable, edible oil, egg and dairy products) (1978-2012)

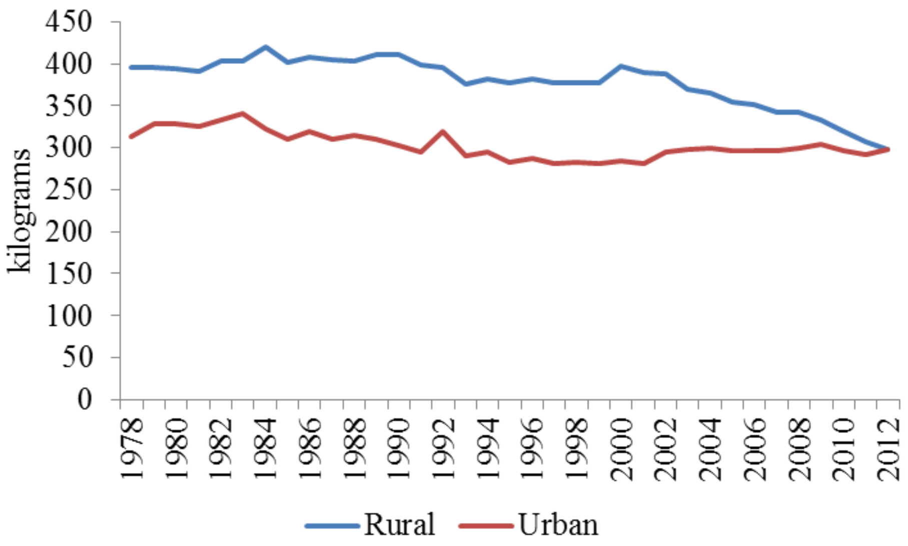




Source: Authors' calculation based data from China Statistical Yearbooks and China Urban Life and Price Yearbooks from 2007 to 2013, and the Great Changes of China's Economy in 60 Years (1947-2007). All were published by the NBS.
Note: Because data on fruit purchase have only been available since 1992, there was a significant increase in the urban household per capita total purchase in 1992. This results in significant drops in the share of grain and vegetables in the same year. Similarly, the rural household per capita total purchase has included fruit since 2003.

It is interesting to see in Figure 2 that the total amount of household per capita food consumption converged to the same level for urban and rural areas at the end of 2012. Figure 1 suggests that this was caused by proportionately more reduction in grain consumption in rural households than in urban ones, while the differences in other foods have remained similar between the two groups. This converging pattern corresponds to the narrowing gap between rural and urban households' per capita total energy intake which has shrunk by 46.6% over the period 1989-2009, although the former's total energy intake remained consistently higher than the latter.

Figure 2 Trends of food consumption of urban and rural households in China

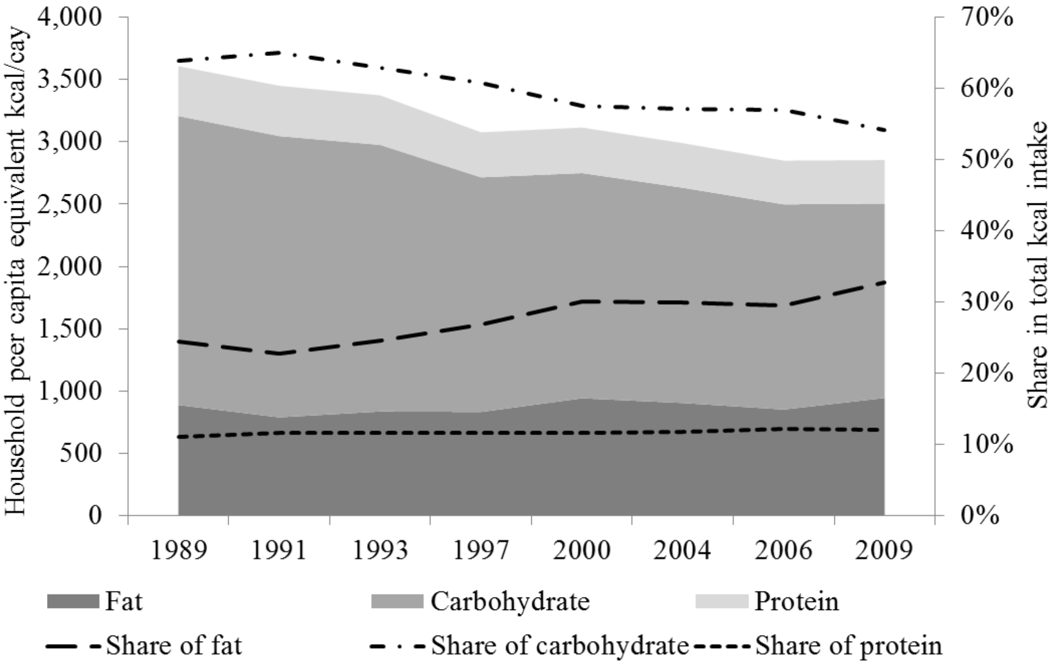


Note: The food consumption indicator is the household per capita annual total consumption of food measured in kg.
Source: See Figure 1.

Our micro data also lend support to the 'income growth-nutrition decline' paradox. The household per capita equivalent net income had quadrupled over the period 1989-2009.[7] By contrast, Figure 3 illustrates clearly a decreasing trend of household total nutrient intake.[8] The household per adult equivalent total nutrient intake per day decreased from 3,629 kcal in 1989 to 2,883 kcal in 2009, registering a proportional decrease of 20.6%. Figure 3 also shows that this decline was mainly driven by reduction in carbohydrate intake: its proportion in household nutrition consumption declined from 64% to 54%. The proportion of fat in total nutrient intake suggests an increasing trend, from 24.5% in 1989 to 32.8% in 2009. The proportion of protein also showed a slight increase, from 11% to 12.1% at the same time. The above pattern reveals that a diet pattern of Chinese households has become unhealthier over time, which is consistent with the changing composition of household food consumption – less grain and vegetables but more oil and meat – as illustrated in Figure 1 and supported by recent studies reviewed in Section 1.

[7] The household equivalence is defined by using the OECD criteria. Refer to Appendix for detailed definition.
[8] The total nutrient intake is calculated as the sum of substrates including fat, carbohydrate and protein. The FAO conversion rates are adopted to calculate total energy measured in kilocalorie from substrates measured in grams. Refer to Appendix 1 for detailed definition.

Figure 3 Nutrient transition



Source: Authors' calculation based on the CHNS.

Although the rural-urban gaps of the quantity of food consumption and total energy intake have narrowed, inequality in nutrition distribution among all households in China has widened over time. The coefficient of variation of household per capita total energy intake decreased from 0.33 in 1989 to 0.29 in 1997, albeit with fluctuations, but rose to 0.55 in 2009. We further calculate the Gini coefficients for household equivalent per capita calorie intake for rural and urban areas separately in Table 1. As income inequality grew in China, household nutrition inequality also accentuated, although by a smaller magnitude. The Gini coefficients of total calorie intake increased by 12.2% and 21.0% in rural and urban areas, respectively. In both rural and urban areas, this increasing inequality stemmed from unequal carbohydrate consumption (from, for example, cereals) and protein. On the contrary, the Gini coefficient of fat intake decreased in rural areas. This is understandable as households shift their diet preferences towards fat and oil when income rises all over China, and especially so among the relatively poor, as recently reviewed in You (2014). Another important message from the inequality statistics is that the FAO's measurement of malnutrition relying on constant coefficient of variation of nutrient intake is likely to be imprecise given significant and complex changes in the nutrition distribution over time. In particular, the number of malnourished people may have been underestimated for China, since the FAO has not taken into account the higher dispersion of nutrient intake within urban and rural areas.[9] This requires more disaggregated and sub-national investigations based on household food consumption surveys such as the CHNS in the present study.[10]

[9] FAO's SOFI 2013 reports a declining trend in undernourishment in China. The proportion of the undernourished in total population has declined from 22.9% in 1990-1992 to 11.4% in 2011-2013 (FAO, 2013). Apart from using calorie availability as an approximation for calorie intake, their methodology assumes a constant probability distribution of individual daily dietary energy consumption. See, for instance, de Haen *et al.* (2011) and de Weerdt *et al.* (2014) for detailed critiques of the FAO methodology.

[10] Further data analyses are found in Appendix2.

Table 1 Household nutritional inequality measured by Gini coefficients

Wave	Rural				Urban			
	Total calories	Fat	Carbohydrate	Protein	Total calories	Fat	Carbohydrate	Protein
1989	0.172	0.348	0.184	0.196	0.162	0.299	0.168	0.172
1991	0.161	0.300	0.182	0.184	0.142	0.250	0.157	0.160
1993	0.170	0.314	0.194	0.192	0.154	0.246	0.172	0.164
1997	0.166	0.291	0.191	0.193	0.153	0.243	0.182	0.179
2000	0.169	0.288	0.189	0.199	0.169	0.264	0.182	0.186
2004	0.180	0.296	0.195	0.201	0.178	0.263	0.190	0.212
2006	0.185	0.331	0.198	0.210	0.179	0.260	0.199	0.206
2009	0.193	0.335	0.187	0.203	0.196	0.300	0.200	0.206
% Change compared to 1989	12.21%	-3.74%	1.63%	3.57%	20.99%	0.33%	19.05%	19.77%

Note: Total and direct calories are measured in kcal. Other nutrients are measured in grams.
Source: Authors' calculation based on the CHNS.

3. Methodology

The analysis is at the disaggregated level for households' intake of different macro nutrients. Let the household i consume the jth nutrient with $j \in \{1,2,3\}$ at t. At the household level for each nutrient j, we regress the logarithmic household equivalent intake of the jth nutrient (K_{ijt}) on a number of correlates of nutrition and health. Theoretically, this specification is related to the model of health production function (Thomas, 1994) where health or nutritional outcomes as an output is a function of a number of inputs (e.g. nutrient intakes and the quantity and quality of health care, and individual and household characteristics) with a standard utility function of household members under a budget constraint for the household.

$$\ln K_{ijt} = \beta_0 + \boldsymbol{\beta}_1 \mathbf{X}_{it} + \boldsymbol{\beta}_2 \mathbf{X}_{pt} + \boldsymbol{\beta}_3 \mathbf{X}_{ct} + \boldsymbol{\beta}_4 \mathbf{X}_{mt} + \sum_s \beta_s D_s + \sum_t \beta_t W_t + \alpha_{ij} + \varepsilon_{ijt} \qquad (1)$$

where the disturbances ε_{ijt} follow an *i.i.d.* normal distribution for each nutrient j; α_{ij} denotes time-invariant and household-specific unobservables determining i's intake of the j^{th} nutrient. The nutrient ($\ln K_{ijt}$) we estimate is either fat, carbohydrate, protein, or the total calorie intake which is derived as the sum of the above three substrates using FAO's (2003) conversion rate.[11] We consider several inputs in household nutrient intake as the independent variables. First, $\mathbf{X}_{it}$ includes the household per capita equivalent net income, demographic transition, education, gender, ethnicity, household wealth indicators that might be relevant to health and nutrition, such as water quality, the toilet type and the main cooking fuels, labour supply, the occupation of household head which would proxy calorie demand caused by certain occupational physical activities, and health status. In particular, we specify five age groups in a 10-year interval and the proportion of adults within a household in each age cohort to account for demographic transition and household composition, respectively. They are posited to capture calorie and nutrition demand. This is particularly important for East Asia where the bulge is moving from the young toward the older end of the working-age years (Bloom, 2011). Together with the economic miracle and wide-ranging economic and social reforms, the demographic transition would have profound influences on nutrition demand. Second, the level and volatility of price indices of various foods are included in $\mathbf{X}_{pt}$ to represent the costs and uncertainties of livelihood as well as cross-price food commodities' substitutions. The food categories cover cereals, oil and fat, meat, eggs and vegetables. Third, we explicitly control for households' knowledge of Chinese balanced diet and eating and living patterns in $\mathbf{X}_{ct}$. The latter is proxied by household preferences for (i) fast food and soft but sweetened drinks, and (ii) physical exercises. Fourth, $\mathbf{X}_{mt}$ incorporates community-level correlates listed in Appendix 1. These include population density, transport, health and social services, development of traditional and modern markets, and an overall economic development index. The provincial and wave dummies are denoted by D_s and W_t, respectively, and also enter into our regressions.

We estimate Eq. (1) using unbalanced panel data with household fixed effects for urban and rural areas, respectively.[12] In this model, there is likely to be endogeneity due to a two-way causality

[11] See Appendix 1 for definitions of these variables.
[12] We have also used the pooled cross-sectional data without household fixed effects as a robustness check. The results of pooled cross-sections are consistent with those with fixed effects, but are not reported due to

between income and nutrition. We refer to the standard instrumental variable estimation (IV) and introduce two instruments: the proportion of farmland that suffered various natural disasters within the province, and the provincial annual growth rate of average wage (per worker). Natural events are believed to be strictly exogenous and have been widely used as instruments for rural households' wellbeing. In this paper, the proportion of farmland suffering from natural disasters is a proxy for the proneness to natural disasters and thus, would affect nutritional intakes. The choice of the second instrument is inspired by the strong link between wage rates and nutrition as indicated by the well-known nutrition-based efficiency wage hypothesis: higher wages allow households to invest more income in health and nutrition (Leibenstein, 1957; Bliss and Stern, 1978a, b; Dasgupta and Ray, 1986, 1987; Dasgupta, 1997; Strauss and Thomas, 1998; Jha et al., 2009). Moreover, the provincial growth rate of wage is presumably correlated with personal wages and income, especially for urban households, but uncorrelated with personal decisions on nutrition consumption.

To reflect heterogeneous nutritional outcomes within urban and rural areas as discussed in Section 2, we combine Canay (2011) and Lee's (2007) approaches to estimate Eq. (1) for urban and rural areas, respectively, by a quantile regression with household fixed effects and endogenous income. Specifically, Eq. (1) is re-written as the following two joint equations:

$$Q_{\ln K_{ijt}|\mathbf{X},\mathbf{Z}}\left(\tau \mid \mathbf{X}, \ln y_{it}\right) = \beta_0(\tau) + \beta_1(\tau)\ln y_{it} + \mathbf{X}\boldsymbol{\beta}_2(\tau) + u_{it} \qquad (2)$$

$$Q_{\ln y_{it}|\mathbf{X},\mathbf{Z}}\left(\lambda \mid \mathbf{X}, \mathbf{Z}\right) = \pi_0(\lambda) + \mathbf{X}\boldsymbol{\pi}_1(\lambda) + \mathbf{Z}\boldsymbol{\pi}_2(\lambda) + v_{it} \qquad (3)$$

where τ and λ denote the quantiles of household per capita equivalent nutrient intake and net income, respectively. $\ln y_{it}$ denotes the household i's natural logarithm of per capita equivalent net income at t. The vector $\mathbf{X}$ includes all correlates in Eq. (1), except income and household fixed effects. $\mathbf{Z}$ contains two excluded instruments as stated before. The disturbances follow $\mathbf{U} \mid \mathbf{X}, \mathbf{Z} \sim U(0,1)$ and $\mathbf{V} \mid \mathbf{X}, \mathbf{Z} \sim U(0,1)$ where $\mathbf{U}$, containing household unobservable characteristics influencing nutrient intake, is correlated with **V**, including unobservables determining the income level (e.g., capability for income generation) and income ($\ln y_{it}$) is uncorrelated with **V** but correlated with $\mathbf{U}$ under the two-way causality between income and nutrition.

In the first step, we estimate Eq. (1) by a fixed-effect panel specification to obtain standard within estimators $\hat{\alpha}_{ij}$. They are used to get rid of fixed effects in $\ln K_{ijt}$ by calculating $\ln \tilde{K}_{ijt} = \ln K_{ijt} - \hat{\alpha}_{ij}$. In the second step, we adopt a linear-in-parameter specification and estimate the λth quantile function conditional on $\mathbf{X}$ and $\mathbf{Z}$ for nutrition by using Eq. (3) to obtain the residual $\hat{v}_{it}$. As the third step, in Eq. (2), $\ln K_{ijt}$ is replaced by $\ln \tilde{K}_{ijt}$ and $\hat{v}_{it}$ is plugged into the τth quantile function conditional on $\mathbf{X}$ and $\mathbf{Z}$ to correct for the endogeneity. Thus, Eq. (2) becomes

$$Q_{\ln \tilde{K}_{ijt}|\mathbf{X},\mathbf{Z}}\left(\tau \mid \mathbf{X}\right) = \beta_0(\tau) + \beta_1(\tau)\ln y_{it} + \mathbf{X}\boldsymbol{\beta}_2(\tau) + \beta_3(\tau)\hat{v}_{it} + u_{it} \qquad (4)$$

limited space. We also test for the equality of coefficients between the urban and rural equations. The F-test rejects the null hypothesis of equal coefficients at the 1% of significance level (*F*-statistic=6.4, *p*-value=0.00).

where λ and τ range from 0.1 to 0.9 with an increment of 0.01.[13] Consistent estimators are defined by

$$\hat{\boldsymbol{\beta}}(\tau) \equiv \underset{\boldsymbol{\beta}\in\Theta}{\arg\min}\, \mathrm{E}_{nT}\left[\rho_\tau\left(\ln \tilde{K}_{ijt} - \hat{\beta}_1 \ln y_{it} - \mathbf{X}\hat{\boldsymbol{\beta}}_2 - \hat{\beta}_3 \hat{v}_{it}\right)\right] \quad (5)$$

$\hat{\beta}_1(\tau)$ picks up the heterogeneous nutritional impact of income at each quantile τ. Other distribution-sensitive nutritional effects are in the vector $\hat{\boldsymbol{\beta}}_2(\tau)$. A significant $\hat{\beta}_3(\tau)$ indicates the existence of endogenous income. The assumption underpinning this three-step estimation strategy is that the impact of household unobserved and time-invariant heterogeneity on nutritional outcomes is same across quantiles.

4. Results and discussion

4.1. *Identifying the determinants of urban and rural households' nutrient intake*

Tables 2-3 summarise the results based on the unbalanced panel with household fixed effects for urban and rural areas, respectively. Two excluded instruments perform well in all columns: they are jointly significantly different from zero in explaining household income according to F-statistics, indicating that the excluded instruments are not weak. In the first stage, as expected, the 'proportion of farmland suffering from natural disasters' is negative and significant and the 'growth rate of provincial average wage' is positive and significant, as shown at the bottom of Table 2 or Table 3. The matrix of reduced form coefficients has full rank according to the Anderson LM test, indicating Eq. (1) is not underidentified. The excluded instruments are uncorrelated with the error term according to Sargan-Hansen test, indicating that there is no overidentification problem, or exclusion restrictions are deemed satisfied.

[13] The values of λ and τ can be different, but we equate them for simplicity.

Table 2 Determinants of household nutrition (urban)

Independent variable	Total calorie	Fat	Carbohydrate	Protein
	(1)	(2)	(3)	(4)
Income				
Ln(Household per capita net income equivalent adult)	0.095 (0.047)**	0.041 (0.057)	0.123 (0.055)**	0.138 (0.059)**
Household demographics				
Age cohort (30≤average age<40)	0.046 (0.049)	0.012 (0.067)	0.053 (0.059)	0.040 (0.056)
Age cohort (40≤average age<50)	-0.004 (0.059)	-0.004 (0.077)	-0.023 (0.071)	0.0003 (0.069)
Age cohort (50≤average age<60)	-0.017 (0.065)	-0.026 (0.083)	-0.047 (0.080)	0.029 (0.079)
Age cohort (average age≥60)	-0.056 (0.082)	0.041 (0.106)	-0.133 (0.097)	-0.098 (0.097)
Proportion of adults	-0.018 (0.073)	0.026 (0.088)	-0.047 (0.088)	-0.041 (0.094)
Gender	0.003 (0.063)	0.042 (0.074)	-0.022 (0.076)	-0.047 (0.080)
Ethnicity	0.036 (0.116)	0.095 (0.160)	-0.024 (0.164)	0.061 (0.158)
Education	-0.029 (0.031)	-0.037 (0.038)	-0.027 (0.039)	-0.031 (0.039)
Household wealth/living conditions				
Water source	-0.016 (0.021)	-0.003 (0.031)	-0.023 (0.024)	0.015 (0.025)
Toilet type	0.004 (0.017)	0.009 (0.022)	0.001 (0.022)	0.014 (0.022)
Cooking fuel	0.012 (0.018)	0.003 (0.023)	0.013 (0.022)	0.024 (0.023)
Occupation physical activity				
Labourer	-0.002 (0.057)	0.023 (0.068)	-0.019 (0.069)	-0.017 (0.069)
Health				
Illness	-0.029 (0.024)	-0.014 (0.030)	-0.028 (0.028)	-0.034 (0.031)
Insurance	-0.033 (0.043)	-0.002 (0.055)	-0.066 (0.050)	-0.034 (0.053)
Level of food price				
Cereals	-0.770 (0.111)	1.548 (1.475)	0.876 (1.322)	0.343 (1.349)
Fat and oil	0.093 (0.367)	0.464 (0.500)	0.191 (0.432)	-0.014 (0.450)
Meat	-3.140 (1.087)***	-3.498 (1.407)**	-3.035 (1.305)**	-2.582 (1.290)**
Eggs	-1.591 (0.874)*	-0.651 (1.131)	-2.322 (1.086)**	-1.786 (1.081)*
Vegetables	1.079 (0.552)*	1.273 (0.681)*	1.061 (0.654)*	0.621 (0.677)
Volatility of food price				
Cereals	-1.373 (1.658)	-3.612 (2.219)*	-0.941 (1.928)	0.617 (2.132)
Fat and oil	-0.786 (0.963)	-3.583 (1.313)***	0.179 (1.169)	-1.717 (1.172)
Meat	2.110 (1.744)	3.097 (2.225)	1.502 (1.993)	1.731 (2.113)
Eggs	4.676 (3.113)	-0.194 (4.046)	6.862 (3.664)*	4.880 (3.775)
Vegetables	-1.436 (0.770)*	-0.736 (0.947)	-2.095 (0.914)**	-0.913 (0.957)
Food knowledge				
Chinese diet knowledge	0.027 (0.024)	0.020 (0.030)	0.044 (0.028)	0.029 (0.030)
Culture and preference				
Diet preference	0.023 (0.019)	0.029 (0.024)	0.007 (0.023)	0.031 (0.024)
Activity preference	-0.008 (0.017)	0.015 (0.022)	-0.019 (0.020)	-0.014 (0.021)
Community				
Population density	-0.006 (0.016)	-0.007 (0.021)	0.002 (0.019)	-0.007 (0.020)
Transport	0.001 (0.007)	0.001 (0.009)	0.001 (0.008)	-0.002 (0.009)

Health services	0.007 (0.007)	0.003 (0.009)	0.011 (0.009)	-0.001 (0.009)
Social services	0.009 (0.005)*	0.008 (0.006)	0.010 (0.006)*	0.009 (0.006)
Traditional market	-0.011 (0.005)**	-0.011 (0.007)	-0.013 (0.006)**	-0.010 (0.007)
Modern market	-0.0001 (0.007)	-0.005 (0.009)	0.0005 (0.008)	0.002 (0.009)
Economy	0.003 (0.007)	0.001 (0.009)	0.002 (0.008)	0.004 (0.009)
Provincial dummy	Yes	Yes	Yes	Yes
Wave dummy	Yes	Yes	Yes	Yes
No. of obs.	2,469	2,469	2,469	2,469
LM statistic for the underidentification test (*p*-value)	8.48 (0.014)	8.48 (0.014)	8.48 (0.014)	8.48 (0.014)
F-statistic for the weak identification (*p*-value)	4.27 (0.014)	4.27 (0.014)	4.27 (0.014)	4.27 (0.014)
Estimation of instruments in the first stage				
Proportion of farmland suffering from natural disasters	-10.621 (4.170)**	-10.621 (4.170)**	-10.621 (4.170)**	-10.621 (4.170)**
Provincial growth rate of average wage	15.820 (6.057)***	15.820 (6.057)***	15.820 (6.057)***	15.820 (6.057)***
Sargan Chi-/Hansen J statistic for the overidentification test (*p*-value)	0.234 (0.628)	0.547 (0.460)	0.01 (0.909)	0.98 (0.323)

Note: The dummy variable indicating the age cohort (age<30) is dropped as the reference group. Estimations are based on data from 2000 to 2009 because variables of food knowledge and two cultural and preference indicators have only been collected since 2000. ***, **, and * denote 1%, 5%, and 10% significance levels in turn. Heteroscedasticity-robust errors are in parentheses.

Table 3 Determinants of household nutrition (rural)

Independent variable	Total calorie	Fat	Carbohydrate	Protein
	(1)	(2)	(3)	(4)
Income				
Ln(Household per capita net income equivalent adult)	-0.077 (0.040)*	-0.053 (0.060)	-0.048 (0.035)	-0.132 (0.055)**
Household demographics				
Age cohort (30≤average age<40)	0.039 (0.032)	0.025 (0.050)	0.053 (0.029)*	0.039 (0.044)
Age cohort (40≤average age<50)	0.018 (0.038)	0.007 (0.059)	0.030 (0.035)	0.018 (0.052)
Age cohort (50≤average age<60)	0.035 (0.048)	0.049 (0.073)	0.021 (0.043)	0.038 (0.065)
Age cohort (average age≥60)	-0.013 (0.057)	0.049 (0.089)	-0.042 (0.051)	-0.037 (0.079)
Proportion of adults	0.045 (0.054)	0.142 (0.079)*	-0.011 (0.049)	0.027 (0.076)
Gender	0.083 (0.058)	0.053 (0.084)	0.076 (0.050)	0.153 (0.080)*
Ethnicity	-0.152 (0.121)	-0.366 (0.202)*	-0.042 (0.103)	-0.141 (0.166)
Education	0.047 (0.029)	0.004 (0.043)	0.059 (0.025)**	0.071 (0.041)*
Household wealth/living conditions				
Water source	0.003 (0.017)	-0.003 (0.027)	0.009 (0.015)	0.011 (0.022)
Toilet type	0.005 (0.010)	0.002 (0.016)	0.009 (0.009)	0.003 (0.013)
Cooking fuel	-0.007 (0.008)	-0.002 (0.013)	-0.011 (0.008)	-0.005 (0.012)
Household labour				
Out-migration	0.088 (0.031)***	0.071 (0.046)	0.074 (0.028)***	0.104 (0.041)**
Local off-farm	0.105 (0.038)***	0.102 (0.057)*	0.072 (0.033)**	0.161 (0.051)***

Occupation physical activity				
Farmer	0.107 (0.052)**	0.143 (0.079)*	0.052 (0.045)	0.149 (0.071)**
Health				
Illness	0.015 (0.018)	0.027 (0.029)	0.005 (0.016)	0.042 (0.024)*
Insurance	0.020 (0.023)	0.035 (0.036)	0.008 (0.020)	0.045 (0.031)
Level of food price				
Cereals	-1.373 (0.994)	2.187 (1.575)	-1.527 (0.891)*	-2.062 (1.280)
Fat and oil	0.445 (0.291)	1.034 (0.465)**	0.423 (0.254)*	0.164 (0.379)
Meat	-0.175 (0.999)	-3.911 (1.565)**	0.089 (0.844)	-0.065 (1.239)
Eggs	3.278 (0.788)***	4.275 (1.219)***	2.283 (0.671)***	1.927 (1.028)*
Vegetables	-0.184 (0.505)	1.622 (0.784)**	-0.668 (0.403)*	-1.284 (0.654)**
Volatility of food price				
Cereals	2.862 (1.349)**	2.267 (2.022)	2.979 (1.194)**	3.908 (1.812)**
Fat and oil	-1.476 (0.704)	-3.939 (1.209)***	-1.132 (0.614)*	-1.628 (0.906)*
Meat	6.299 (1.567)***	13.857 (2.495)***	3.822 (1.384)***	4.691 (2.118)**
Eggs	-0.573 (1.900)	3.347 (3.071)	-0.847 (1.743)	1.562 (2.467)
Vegetables	-0.528 (0.609)	-2.687 (0.954)***	-0.169 (0.467)	0.912 (0.778)
Food knowledge				
Chinese diet knowledge	0.023 (0.023)	0.079 (0.037)**	-0.003 (0.020)	0.033 (0.030)
Culture and preference				
Diet preference	0.010 (0.013)	-0.034 (0.023)	0.001 (0.013)	-0.008 (0.020)
Activity preference	0.011 (0.013)	0.004 (0.021)	0.003 (0.011)	0.025 (0.017)
Community				
Population density	-0.002 (0.014)	-0.014 (0.020)	0.008 (0.012)	0.014 (0.020)
Transport	0.005 (0.004)	0.013 (0.007)**	0.001 (0.004)	0.005 (0.006)
Health services	0.001 (0.004)	0.009 (0.007)	-0.003 (0.004)	-0.003 (0.006)
Social services	0.009 (0.004)**	0.009 (0.006)	0.012 (0.004)***	0.011 (0.005)**
Traditional market	-0.004 (0.003)	-0.014 (0.005)***	0.0003 (0.003)	-0.006 (0.004)
Modern market	-0.011 (0.005)**	-0.007 (0.008)	-0.009 (0.004)**	-0.006 (0.007)
Economy	0.003 (0.005)	0.013 (0.007)*	0.001 (0.004)	-0.0005 (0.007)
Provincial dummy	Yes	Yes	Yes	Yes
Wave dummy	Yes	Yes	Yes	Yes
No. of obs.	4,066	4,066	4,066	4,066
LM statistic for the underidentification test (*p*-value)	10.76 (0.005)	10.76 (0.005)	10.76 (0.005)	10.76 (0.005)
F-statistic for the weak identification (*p*-value)	5.41 (0.005)	5.41 (0.005)	5.41 (0.005)	5.41 (0.005)
Estimation of instruments in the first stage				
Proportion of farmland suffering from natural disasters	-7.985 (4.053)**	-7.985 (4.053)**	-7.985 (4.053)**	-7.985 (4.053)**
Provincial growth rate of average wage	15.780 (4.814)***	15.780 (4.814)***	15.780 (4.814)***	15.780 (4.814)***
Sargan Chi-/Hansen J statistic for the overidentification test (*p*-value)	0.70 (0.500)	4.44 (0.035)	1.39 (0.180)	3.80 (0.051)

Note: See Footnote of Table 2.

Columns 1-4 of Table 2 show positive and significant impact of income on total calorie intake and its substrates except fat for which the income is positive and statistically insignificant. The income elasticity of protein (0.138) is slightly higher than that of carbohydrate (0.123). Household nutrition is insensitive to the demographic transition, household composition, education,[14] ethnicity, indicators for wealth and living conditions, and health status.

Rural households show broadly similar results of various household demographic characteristics in Table 3 as their urban counterparts,[15] except for income. Negative income-nutrition nexus surfaces due to the negative impact of income on protein (Columns 1 and 4 of Table 3).

We further specify three sources of income - agriculture, household business, and wage income - and re-estimate Tables 2-3, in order to decode the above mixed results between rural and urban households. The negative impact of income on protein comes from agricultural and wage incomes, while 1% increase in household business income can raise protein intake by 0.329% at the 10% significance level. This seems to be inconsistent with the traditional view on agriculture-nutrition link in developing countries or the poverty reducing effect of agricultural income in developing countries (Imai and Gaiha, 2014) as well as in rural China (Imai and You, 2013). Based on a number of empirical findings in the developing world, Fan and Brzeska's (2012) argue that the growth pattern also matters in addition to income growth *per se*. They summarise factors affecting the link between growth and nutrition: it is the growth of (staple) crop income that raises rural households' calorie intake rather than that of livestock income. We investigate this intriguing result by further inserting the proportions of crop and livestock incomes in total agricultural income in the above regression (with three specified income sources) for rural households. A one additional percentage of proportion of crop income can increase the household total energy intake by 0.786% at the 10% significance level, which stems from 7% and 1.168% increases in carbohydrates and protein, respectively. By contrast, the estimator of the proportion of livestock income is statistically insignificant in all the cases.[16]

For urban households in Table 2, we replaced the household's overall net income indicator by logarithmic household per capita equivalent net business and wage incomes and re-estimated all regressions. Both promote urban households' total nutrition intake at the 10% significance level. The magnitude of the former (0.139) is statistically larger than that of the latter (0.013) at the 10% significance level. The channel underlying this better nutritional outcome is their positive impacts on carbohydrates (0.184 and 0.015 at the 10% significance level for business and wage incomes, respectively) and protein (0.205 and 0.018 at the 10% significance level for business wage incomes, respectively) compared with fat (0.051 and 0.012 without statistical significance for business and wage incomes, respectively). [17]

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[14] We re-estimated Table 2 by replacing household average education by males' and females' average education levels. Only males' education significantly reduce total energy intake (-0.054) through less fat consumption (-0.075), both at the 5% significance levels.

[15] We also re-estimated Table 3 by replacing household average education with male and female adults' average education levels. They are statistically insignificant in all cases.

[16] Fan and Brzeska (2012) did not provide a clear reason for why crop income raises rural households' calorie intake more than livestock income. It is conjectured that the former may increase the crops set aside for their own consumption or may require more physical intense activity. Our data lend some support to the latter. Specifically, for each adult family member (≥ 18 years old), we calculated his/her proportion of time doing heavy physical activities (e.g., farming) in total time doing all physical activities in a typical week and then, took the average among all adult members within the household. It correlates closely to the proportion of the household's crop income in its total agricultural income with the correlation coefficient of 0.38, but not with the proportion of livestock income with the correlation coefficient of 0.044. Both coefficients are statistically significant at the 1% level.

[17] Econometric results for these disaggregated cases will be furnished on request.

As expected, rural households headed by farmers consume 14.3% more fat (Column 2 of Table 3) and 14.9% more protein (Column 4 of Table 3), leading to overall 10.7% more total energy (Column 1 of Table 3), compared with non-farmer headed ones. Both out-migration and local off-farm employment help increase carbohydrates and protein and total energy (Columns 1, 3 and 4 of Table 3). The magnitude of the impact of local off-farm employment is only significantly larger than that of out-migration in the case of protein: for each column of 1, 3 and 4, the Wald test only rejects the null hypothesis of equal magnitude of their estimates at the 10% significance level in Column 4 of Table 3. Fat intake also rises by 0.102% if there is a one more percentage point of household members obtaining local off-farm employment, but is unresponsive to out-migration (Column 2 of Table 3).

Food prices appear to be the main sources of differences in both urban and rural households' nutrition status. In Table 2, urban households' intake of total nutrition and substrates are not affected by the level of prices of cereals, but would be lowered by higher prices of meat and eggs. The magnitude of these negative effects is large: a one percent increase in the meat (egg) price could reduce the household's total energy intake by 3.14% (1.59%) in Column 1 (2) of Table 3. The reduction caused by the rising meat price originates from all three substrates, especially fat (-3.498% in Column 2 of Table 2), while that caused by a higher egg price comes from carbohydrates (-2.322% in Column 3 of Table 2) and protein (-1.786% in Column 4 of Table 2). Higher vegetable prices are associated with more energy intake (1.079 in Column 1 of Table 2) through their positive impact on fat and carbohydrates intake (Columns 2-3 of Table 2). This indicates that vegetables are likely to be inferior goods for urban households, while meat and eggs are normal goods. Uncertainties in terms of volatilities of prices of cereals and 'fat and oil' do not appear to hurt urban households' total energy intake, but decrease fat consumption. Volatilities in vegetable prices decrease total energy intake through its negative impact on carbohydrates (Columns 1 and 3 of Table 2). It is worth noting the large positive effect of volatility of egg price (6.862 in Column 3 of Table 2). There might be considerable substitution of starchy foods for eggs under the price shock of eggs.

On the contrary, Table 3 shows that rural households would consume more fat, carbohydrates and protein under higher egg prices and thus, more total energy. Eggs are inferior goods as found in Bishop *et al.* (2010) and Du *et al.* (2004) by using the CHNS as well. Considering our result for urban areas, their finding may have been driven by rural rather than urban households. Higher fat and oil prices are associated with more consumption of fat and carbohydrates, which indicates that fat or oil is also an inferior good for rural households. A higher price of vegetables suppresses carbohydrates and protein but encourages fat consumption. As a result, total energy is not responsive to it. It is worth noting consistently positive coefficient estimates of volatility of meat price on total energy and all three substrates with considerably large magnitudes (varying from 3.822 for carbohydrate in Column 3 of Table 3 to 13.857 for fat in Column 2 of Table 3). This may be driven by rural households' strong preferences of meat. As shown in Column 2 of Table 3, households tend to consume more fat proportionately as well under volatile meat prices and even after knowing what a balanced diet should be (0.079 in Column 2 Table 3).

As found by Shimokawa (2013), acquiring more knowledge of healthy diet does not necessarily raise nutrient intake, except fat for rural households (Column 2 of Table 3), as indicated by insignificant estimated coefficients of 'dietary knowledge' in Tables 2-3. . Switch in preferences towards energy- and sugar-rich diet or doing more physical exercises is irrelevant for higher nutrition for both urban and rural households.

Among various community indicators, only social services increase total energy intake through carbohydrates for urban households (Columns 1 and 3 of Table 2) and through carbohydrates and protein for rural households (Columns 1, 3 and 4 of Table 3). Traditional markets are likely to deter the growth of total energy intake through carbohydrates for urban households and fat for rural households.

4.2. Distributional nutritional effects within urban and rural areas

We proceed to examine the distributional nutritional effects for urban and rural households in Tables 4 and 5, respectively, by using quantile regressions with household fixed effects.

Table 4 Distributional impact on household nutrient intake (urban)

Independent variable	Fat			Carbohydrate			Protein		
	τ=0.1 (1)	τ=0.5 (2)	τ=0.9 (3)	τ=0.1 (4)	τ=0.5 (5)	τ=0.9 (6)	τ=0.1 (7)	τ=0.5 (8)	τ=0.9 (9)
Income									
Ln(Household per capita net income equivalent adult)	0.006 (0.043)	0.041 (0.195)	-0.224 (0.298)	0.149 (0.047)***	0.127 (0.154)	0.273 (0.245)	0.131 (0.036)***	0.138 (0.161)	0.095 (0.264)
Household demographics									
Age cohort (30≤average age<40)	-0.023 (0.042)	0.012 (0.011)	0.047 (0.036)	0.064 (0.041)	0.053 (0.008)***	0.051 (0.021)**	0.021 (0.030)	0.040 (0.009)***	0.078 (0.022)***
Age cohort (40≤average age<50)	0.001 (0.041)	-0.004 (0.009)	0.016 (0.045)	-0.060 (0.033)*	-0.023 (0.007)***	0.028 (0.033)	-0.056 (0.030)*	0.0003 (0.008)	0.069 (0.032)**
Age cohort (50≤average age<60)	-0.067 (0.049)	-0.026 (0.012)**	-0.010 (0.054)	-0.086 (0.035)**	-0.047 (0.009)***	0.009 (0.036)	-0.034 (0.036)	0.029 (0.010)***	0.102 (0.042)**
Age cohort (average age≥60)	-0.003 (0.084)	0.042 (0.050)	-0.018 (0.104)	-0.118 (0.082)	-0.132 (0.040)***	-0.037 (0.084)	-0.133 (0.058)**	-0.098 (0.042)**	-0.064 (0.093)
Proportion of adults	-0.011 (0.128)	0.026 (0.075)	-0.067 (0.071)	-0.014 (0.122)	-0.046 (0.060)	-0.027 (0.058)	-0.039 (0.100)	-0.041 (0.062)	-0.082 (0.070)
Gender	0.110 (0.051)**	0.042 (0.022)**	0.063 (0.030)**	-0.010 (0.053)	-0.022 (0.017)	-0.037 (0.023)	-0.038 (0.042)	-0.047 (0.018)***	-0.030 (0.023)
Ethnicity	0.252 (0.059)***	0.095 (0.022)***	-0.137 (0.036)***	0.061 (0.043)	-0.024 (0.009)***	-0.164 (0.027)***	0.150 (0.036)***	0.061 (0.009)***	-0.095 (0.030)***
Education	0.020 (0.096)	-0.037 (0.065)	0.043 (0.076)	-0.095 (0.103)	-0.028 (0.051)	-0.040 (0.062)	-0.021 (0.079)	-0.031 (0.054)	0.002 (0.068)
Household wealth/living conditions									
Water source	-0.026 (0.023)	-0.003 (0.006)	0.003 (0.028)	-0.060 (0.015)***	-0.023 (0.005)***	-0.015 (0.016)	-0.003 (0.022)	0.015 (0.005)***	0.035 (0.013)***
Toilet type	0.031 (0.032)	0.009 (0.017)	0.042 (0.040)	-0.017 (0.030)	0.001 (0.014)	-0.024 (0.033)	0.009 (0.024)	0.014 (0.014)	0.022 (0.034)
Cooking fuel	0.006 (0.023)	0.003 (0.017)	0.009 (0.016)	-0.007 (0.016)	0.012 (0.014)	0.016 (0.012)	0.021 (0.017)	0.024 (0.014)*	0.028 (0.015)*
Occupation physical activity									
Labourer	0.175 (0.150)	0.023 (0.010)**	-0.013 (0.034)	-0.056 (0.153)	-0.019 (0.008)**	0.009 (0.024)	0.052 (0.123)	-0.017 (0.009)*	-0.013 (0.023)
Health									
Illness	0.0005 (0.030)	-0.014 (0.006)**	-0.024 (0.026)	-0.022 (0.023)	-0.028 (0.005)***	-0.044 (0.021)**	-0.022 (0.022)	-0.034 (0.006)***	-0.044 (0.020)**
Insurance	0.153 (0.180)	-0.002 (0.104)	0.066 (0.053)	-0.138 (0.189)	-0.068 (0.082)	-0.072 (0.041)*	0.037 (0.159)	-0.034 (0.087)	-0.035 (0.043)
Level of food price									
Cereals	-1.020 (1.843)	1.548 (1.133)	1.894 (1.307)	0.299 (1.703)	0.899 (0.899)	-0.461 (1.438)	-0.907 (1.536)	0.343 (0.933)	-0.121 (1.194)
Fat and oil	-0.194 (0.537)	0.464 (0.191)**	0.571 (0.474)	-0.321 (0.453)	0.196 (0.164)	-0.101 (0.383)	-0.623 (0.424)	-0.014 (0.169)	-0.042 (0.378)
Meat	-3.504 (1.538)**	-3.497 (0.808)***	-4.582 (1.803)**	-2.211 (1.116)**	-3.049 (0.644)***	-1.505 (1.426)	-2.698 (1.019)***	-2.582 (0.675)***	-2.555 (1.264)**
Eggs	-1.460 (0.923)	-0.651 (0.668)	-1.860 (1.251)	-3.185 (0.696)***	-2.333 (0.525)***	-0.684 (0.964)	-1.979 (0.804)**	-1.786 (0.553)***	-1.595 (0.994)
Vegetables	-0.005 (1.100)	1.273 (0.205)***	0.769 (0.696)	2.279 (1.123)**	1.061 (0.169)***	0.375 (0.508)	1.000 (0.968)	0.621 (0.182)***	0.850 (0.526)
Volatility of food price									
Cereals	-2.741 (2.557)	-3.612 (0.711)***	-2.730 (2.062)	-1.954 (2.280)	-0.944 (0.517)*	1.552 (1.460)	2.676 (2.129)	0.617 (0.608)	0.659 (1.717)
Fat and oil	-3.524 (1.711)**	-3.583 (0.515)***	-3.106 (0.944)***	0.638 (1.275)	0.169 (0.408)	-0.455 (0.864)	-1.538 (1.063)	-1.717 (0.402)***	-1.790 (0.728)**
Meat	5.139 (2.850)*	3.097 (0.766)***	1.938 (2.472)	-0.989 (2.424)	1.516 (0.627)**	1.999 (1.969)	2.708 (2.343)	1.731 (0.657)***	0.752 (1.983)
Eggs	-0.892 (3.913)	-0.194 (2.580)	-1.274 (3.260)	5.757 (2.857)**	6.907 (2.051)***	3.819 (2.636)	6.419 (2.654)**	4.880 (2.170)**	1.687 (2.416)
Vegetables	0.600 (1.296)	-0.736 (0.368)**	0.353 (0.779)	-3.133 (1.394)**	-2.100 (0.293)***	-1.242 (0.592)**	-0.880 (1.100)	-0.913 (0.314)***	-0.680 (0.620)
Food knowledge									
Chinese diet knowledge	0.025 (0.054)	0.020 (0.024)	0.041 (0.022)*	-0.003 (0.060)	0.044 (0.019)**	0.055 (0.016)***	0.028 (0.040)	0.029 (0.020)	0.028 (0.017)*
Culture and preference									
Diet preference	0.041 (0.023)*	0.029 (0.005)***	0.027 (0.019)	0.023 (0.019)	0.007 (0.004)*	0.022 (0.013)	0.022 (0.017)	0.031 (0.004)***	0.031 (0.014)**
Activity preference	0.040 (0.027)	0.015 (0.008)*	0.015 (0.017)	-0.048 (0.023)**	-0.019 (0.006)***	0.013 (0.013)	-0.018 (0.020)	-0.014 (0.007)**	0.022 (0.012)*
Community									

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Population density	0.002 (0.012)	-0.007 (0.002)***	-0.011 (0.009)	-0.010 (0.009)	0.002 (0.002)	0.013 (0.005)***	-0.012 (0.008)	-0.007 (0.002)***	-0.003 (0.006)
Transport	-0.004 (0.010)	0.001 (0.002)	-0.002 (0.005)	0.007 (0.009)	0.001 (0.002)	0.007 (0.004)*	-0.006 (0.009)	-0.002 (0.002)	-0.002 (0.004)
Health services	-0.002 (0.007)	0.003 (0.002)*	0.002 (0.007)	0.005 (0.005)	0.011 (0.002)***	0.013 (0.006)**	-0.015 (0.004)***	-0.001 (0.002)	0.001 (0.006)
Social services	0.013 (0.006)**	0.008 (0.001)***	0.001 (0.005)	0.015 (0.004)***	0.010 (0.001)***	0.006 (0.003)*	0.015 (0.004)***	0.009 (0.001)***	0.004 (0.004)
Traditional market	-0.017 (0.006)***	-0.011 (0.001)***	-0.011 (0.004)***	-0.009 (0.006)*	-0.013 (0.001)***	-0.015 (0.003)***	-0.006 (0.004)	-0.010 (0.001)***	-0.010 (0.003)***
Modern market	-0.002 (0.006)	-0.005 (0.003)*	0.009 (0.007)	-0.002 (0.005)	0.0004 (0.002)	0.004 (0.004)	-0.004 (0.005)	0.002 (0.002)	0.009 (0.005)*
Economy	0.009 (0.007)	0.001 (0.008)	0.007 (0.009)	0.017 (0.009)*	0.001 (0.006)	0.001 (0.007)	0.012 (0.006)**	0.004 (0.007)	0.008 (0.008)
Provincial dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	3,442	3,442	3,442	3,442	3,442	3,442	3,442	3,442	3,442
R^2	0.267	0.309	0.264	0.702	0.715	0.687	0.717	0.727	0.704
Machado-Santos Silva test for heteroskedasticit, Chi-square (*p*-value)	48.90 (0.000)	24.32 (0.000)	6.30 (0.043)	20.62 (0.000)	124.26 (0.000)	158.07 (0.000)	14.76 (0.000)	158.49 (0.000)	188.50 (0.000)

Note: ***, **, and * denote 1%, 5%, and 10% significance levels in turn. Heteroscedasticity-robust errors are in parentheses.

Table 5 Distributional impact on household nutrient intake (rural)

Independent variable	Fat			Carbohydrate			Protein		
	τ=0.1 (1)	τ=0.5 (2)	τ=0.9 (3)	τ=0.1 (4)	τ=0.5 (5)	τ=0.9 (6)	τ=0.1 (7)	τ=0.5 (8)	τ=0.9 (9)
Income									
Ln(Household per capita net income equivalent adult)	-0.021 (0.031)	-0.053 (0.077)	-0.593 (0.283)**	0.064 (0.036)*	0.211 (0.204)	-0.249 (0.360)	-0.011 (0.035)	0.053 (0.212)	-0.172 (0.327)
Household demographics									
Age cohort (30≤average age<40)	-0.011 (0.038)	0.025 (0.013)*	0.002 (0.042)	0.041 (0.047)	0.055 (0.039)	0.044 (0.052)	0.064 (0.048)	0.060 (0.037)*	0.047 (0.049)
Age cohort (40≤average age<50)	-0.013 (0.032)	0.007 (0.015)	-0.035 (0.048)	-0.047 (0.049)	0.051 (0.046)	0.020 (0.060)	0.035 (0.043)	0.070 (0.043)*	0.062 (0.058)
Age cohort (50≤average age<60)	-0.045 (0.040)	0.049 (0.015)***	-0.001 (0.057)	-0.012 (0.061)	0.066 (0.050)	0.061 (0.071)	0.110 (0.051)**	0.107 (0.049)**	0.088 (0.067)
Age cohort (average age≥60)	0.027 (0.071)	0.049 (0.046)	-0.015 (0.100)	0.036 (0.096)	0.219 (0.126)*	0.079 (0.128)	0.096 (0.087)	0.152 (0.131)	0.129 (0.113)
Proportion of adults	0.172 (0.050)***	0.142 (0.016)***	0.130 (0.054)**	0.047 (0.085)	0.197 (0.054)***	0.071 (0.074)	0.084 (0.062)	0.138 (0.054)**	0.146 (0.066)**
Gender	0.023 (0.032)	0.053 (0.014)***	0.080 (0.034)**	0.007 (0.046)	-0.046 (0.044)	-0.047 (0.045)	0.071 (0.038)*	-0.004 (0.043)	0.025 (0.041)
Ethnicity	-0.321 (0.078)***	-0.366 (0.012)***	-0.341 (0.137)**	-0.011 (0.471)	0.089 (0.069)	-0.037 (0.123)	0.064 (0.169)	0.063 (0.062)	0.031 (0.106)
Education	-0.025 (0.026)	0.004 (0.022)	0.102 (0.067)	0.092 (0.032)***	0.007 (0.057)	0.115 (0.082)	0.044 (0.028)	0.011 (0.060)	0.064 (0.072)
Household wealth/living conditions									
Water source	-0.009 (0.025)	-0.003 (0.004)	-0.0003 (0.017)	-0.043 (0.029)	-0.032 (0.016)**	-0.027 (0.021)	-0.049 (0.027)*	-0.024 (0.014)*	-0.015 (0.023)
Toilet type	0.009 (0.010)	0.002 (0.006)	0.037 (0.022)*	0.055 (0.014)***	0.034 (0.016)**	-0.044 (0.030)	0.033 (0.014)	0.012 (0.016)	0.006 (0.028)
Cooking fuel	-0.010 (0.011)	-0.002 (0.005)	0.014 (0.016)	0.027 (0.016)*	0.010 (0.014)	0.036 (0.018)	0.016 (0.014)	-0.007 (0.014)	0.016 (0.018)
Household labour									
Out-migration	0.123 (0.036)***	0.071 (0.017)***	0.010 (0.016)	-0.059 (0.045)	-0.007 (0.046)	0.065 (0.030)**	0.014 (0.044)	0.031 (0.048)	0.032 (0.024)
Local off-farm	0.057 (0.066)	0.102 (0.025)***	0.184 (0.051)***	-0.086 (0.076)	-0.008 (0.067)	0.067 (0.064)	0.011 (0.076)	0.072 (0.070)	0.098 (0.060)*
Occupation physical activity									
Farmer	0.087 (0.138)	0.143 (0.013)***	0.082 (0.024)***	-0.364 (0.162)**	-0.088 (0.038)**	-0.099 (0.031)***	-0.160 (0.160)	0.043 (0.038)	-0.014 (0.028)
Health									
Illness	0.087 (0.022)***	0.027 (0.005)***	0.029 (0.023)	-0.031 (0.033)	0.005 (0.020)	-0.005 (0.028)	0.042 (0.027)	0.039 (0.018)**	0.024 (0.024)
Insurance	0.030 (0.052)	0.035 (0.027)	0.140 (0.067)**	0.009 (0.074)	-0.027 (0.075)	0.023 (0.082)	0.012 (0.057)	-0.006 (0.076)	-0.080 (0.079)

Level of food price									
Cereals	5.497 (1.683)**	2.187 (0.458)***	3.123 (1.472)**	8.258 (2.201)***	-0.464 (1.350)	1.147 (2.103)	4.912 (2.028)**	-0.308 (1.338)	-1.606 (1.600)
Fat and oil	1.280 (0.562)**	1.034 (0.161)***	1.090 (0.505)**	1.624 (0.832)*	0.743 (0.465)	0.527 (0.621)	1.099 (0.756)	0.641 (0.480)	0.567 (0.531)
Meat	-6.046 (1.511)***	-3.911 (0.380)***	-6.399 (1.656)***	-8.840 (2.082)***	-2.304 (1.202)*	-0.462 (2.160)	-6.072 (1.840)***	-1.946 (1.108)*	0.655 (1.877)
Eggs	3.035 (1.132)***	4.275 (0.249)	3.349 (1.187)***	2.203 (1.675)	2.561 (0.799)***	4.045 (1.513)***	3.037 (1.412)**	3.320 (0.777)***	5.498 (1.276)***
Vegetables	1.216 (1.025)	1.622 (0.210)***	3.165 (0.968)***	2.925 (1.177)**	0.587 (0.641)	0.803 (1.101)	1.832 (1.356)	0.368 (0.594)	1.987 (1.029)*
Volatility of food price									
Cereals	4.284 (2.331)*	2.267 (0.554)***	-1.999 (2.294)	4.892 (3.503)	3.324 (1.875)*	0.871 (2.624)	5.307 (3.288)	1.557 (1.706)	-2.981 (2.830)
Fat and oil	-5.677 (1.442)***	-3.939 (0.395)***	-3.109 (1.060)***	-9.979 (2.134)***	-3.008 (1.130)***	-1.525 (1.598)	-8.385 (1.846)***	-2.943 (1.217)**	-1.595 (1.401)
Meat	14.337 (3.131)***	13.857 (0.720)***	14.240 (2.510)***	16.315 (4.646)***	8.854 (2.100)***	6.201 (3.036)**	15.873 (4.288)***	8.592 (2.036)***	3.040 (2.978)
Eggs	5.471 (3.760)	3.347 (0.908)***	3.136 (3.299)	9.458 (5.377)*	0.727 (2.832)	-5.085 (4.554)	5.248 (4.744)	-2.420 (2.706)	-10.611 (3.910)
Vegetables	-2.608 (1.224)**	-2.687 (0.258)***	-3.784 (0.955)***	-4.426 (1.486)***	-1.878 (0.786)**	-1.188 (1.124)	-2.708 (1.631)*	-1.203 (0.766)	-2.574 (1.050)
Food knowledge									
Chinese diet knowledge	0.056 (0.043)	0.079 (0.013)***	0.157 (0.041)***	-0.060 (0.056)	-0.003 (0.039)	0.050 (0.043)	-0.030 (0.055)	-0.017 (0.038)	0.037 (0.043)
Culture and preference									
Diet preference	-0.054 (0.020)***	-0.034 (0.005)***	0.045 (0.029)	-0.057 (0.025)**	-0.033 (0.017)*	-0.014 (0.036)	-0.032 (0.022)	-0.038 (0.016)**	0.0005 (0.034)
Activity preference	-0.008 (0.020)	0.004 (0.007)	0.024 (0.022)	0.038 (0.029)	0.015 (0.020)	0.026 (0.029)	0.017 (0.027)	0.010 (0.021)	0.015 (0.025)
Community									
Population density	-0.005 (0.008)	-0.014 (0.002)***	-0.036 (0.008)***	0.018 (0.012)	0.0005 (0.008)	-0.014 (0.010)	0.009 (0.012)	-0.002 (0.007)	-0.013 (0.025)
Transport	0.013 (0.005)***	0.013 (0.002)***	0.017 (0.006)***	0.018 (0.008)**	0.013 (0.005)**	0.015 (0.008)*	0.024 (0.008)***	0.017 (0.005)***	0.012 (0.008)
Health services	0.009 (0.006)*	0.009 (0.001)***	0.012 (0.004)***	0.008 (0.008)	0.009 (0.004)**	0.018 (0.005)***	-0.005 (0.008)	0.003 (0.004)	0.009 (0.005)*
Social services	0.010 (0.005)*	0.009 (0.001)***	0.004 (0.004)	0.002 (0.007)	0.011 (0.004)***	0.007 (0.006)	-0.005 (0.007)	0.007 (0.004)*	0.009 (0.006)
Traditional market	-0.015 (0.003)***	-0.014 (0.001)***	-0.017 (0.004)***	-0.002 (0.005)	-0.001 (0.003)	-0.004 (0.006)	-0.004 (0.004)	-0.004 (0.003)	-0.008 (0.005)*
Modern market	-0.004 (0.006)	-0.007 (0.002)***	-0.006 (0.005)	0.014 (0.007)*	0.001 (0.006)	-0.009 (0.006)	0.008 (0.007)	-0.002 (0.006)	-0.006 (0.006)
Economy	0.014 (0.009)	0.013 (0.001)***	0.010 (0.006)	0.027 (0.011)**	0.023 (0.005)***	0.012 (0.007)*	0.016 (0.010)	0.006 (0.005)	0.013 (0.007)*
Provincial dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	5,583	5,583	5,583	5,583	5,583	5,583	5,583	5,583	5,583
R^2	0.352	0.411	0.370	0.172	0.202	0.141	0.209	0.247	0.230
Machado-Santos Silva test for heteroskedasticit, Chi-square (*p*-value)	29.70 (0.000)	44.53 (0.000)	18.01 (0.000)	236.01 (0.000)	141.12 (0.000)	0.918 (0.632)	121.53 (0.000)	98.94 (0.000)	24.80 (0.000)

Note: ***, **, and * denote 1%, 5%, and 10% significance levels in turn. Heteroscedasticity-robust errors are in parentheses.

Columns 4 and 7 of Table 4 show that while the income elasticities of carbohydrates and protein for urban households in Table 2 are positive in the population deficient in these two nutrients (at the 10% point, or τ =0.1 of their conditional distributions), these elasticities cease to be statistically significant among better-nourished households (at median or 90%, or τ =0.5 or 0.9 of their conditional distributions). Younger households with average age of household members between 30 and 40 years and with moderate nutrient level consume more carbohydrate and protein (Columns 5-6 and 7-8 of Table 4), while among the older the intake decreases at a faster speed. In contrast, the least nourished households only experience the negative impact of age, especially the cohorts aged above 40 (Columns 4 and 7 of Table 4). Ethnic differences matter. Belonging to the ethnic minority group is associated with lower intake of fat, carbohydrate, or protein, at the 90% point of its conditional distribution, that is, among the better-nourished, ethnic minorities tend to take a smaller amount of nutrient than the ethnic majority, *ceterus paribus*. However, this pattern is reversed for fat or protein at the 10% point of its conditional distribution. Among the malnourished, ethnic minorities tend to take a larger amount of nutrient than the ethnic majority, *ceterus paribus*.

Higher prices of meat are detrimental for all households' nutrition, except for those having consumed many carbohydrates (Column 6 of Table 4). Food knowledge and other cultural and dietary-preference factors also become statistically significant for certain groups. However, it is those having at least modest nutrition rather than the least nourished who tend to consume more fat, carbohydrate and protein after knowing more about healthy diet. Transport and health services also benefit those with high carbohydrate intake (Column 6 of Table 4), while social services and overall economic development are associated with nutrition improvement for those with the lowest carbohydrate and protein intake (Columns 4-8 of Table 4).

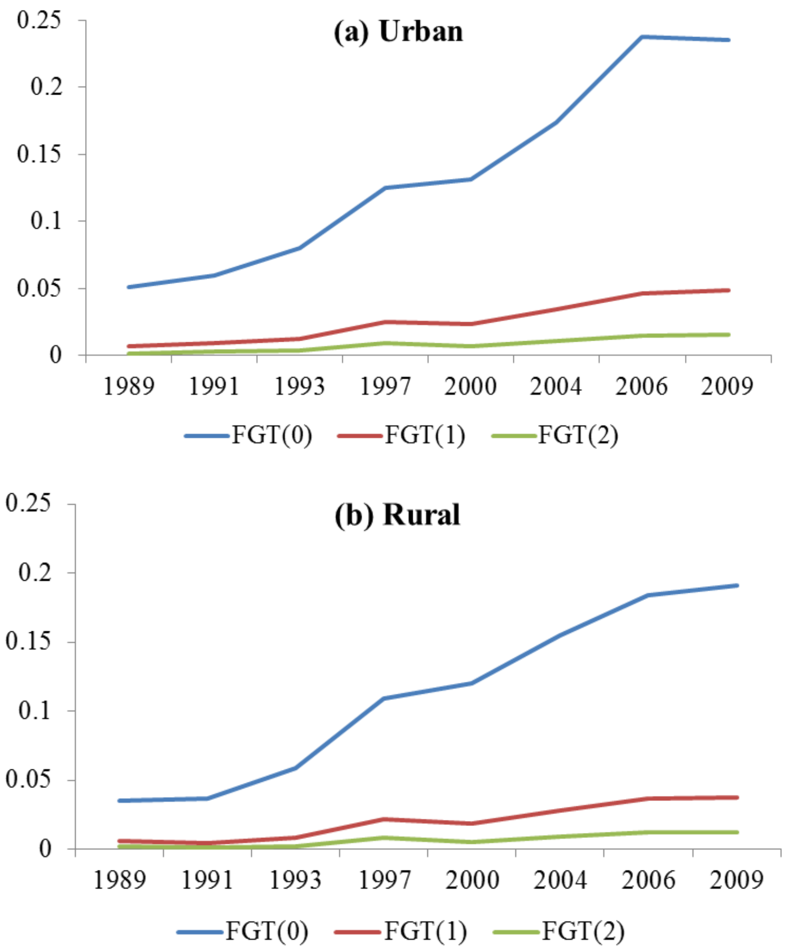
For rural households, the positive income-nutrition link is found for carbohydrate at the 10% point in its conditional distribution (Column 4 of Table 5), while the *negative* link is found between income and fat among those who are already consuming much oil and fat (at the 90% point) (Column 3 of Table 5). Ethnic minorities tend to consume less fat regardless of their position in the nutritional distribution (Columns 1-3 of Table 5), but no ethnic differences exist in other nutrients. Out-migration can increase rural households' fat intake for those with lowest fat consumption (Columns 1-2 of Table 5), and this impact is proportionately large for the least nourished. However, only well-nourished households benefit from out-migration and raise their carbohydrate (Column 6 of Table 5). Similarly, local off-farm employment benefit fat and protein intake for at least moderately nourished households (Columns 2-3 and 9 of Table 5), but are ineffective means for improving nutritional status of those with lowest and highest nutrient intake.

4.3. Implications for nutrition poverty

Decreasing nutrient intake has given rise to nutrition poverty. By using the cut-off at 2,100 kcal per person per day as suggested by Park and Wang (2001), Figure 4 depicts the profile of nutrition poverty in China.[18] The nutrition poverty rate (FGT(0)), nutrition poverty gap (FGT(1)) and its square (FGT(2)) all increased in both urban and rural areas, with the urban households seeing slightly higher magnitude due to its lower level of total energy intake. This implies that those just escaped from income poverty might still be deficient in nutrition. Meanwhile, the remaining income poor have to confront the dual burden of both income poverty and nutritional deficiency, which could result in nutrition-poverty traps in the long term.

[18] The pattern in Figure 4 remains same for a higher nutrition poverty line of 2,400 kcal which is also suggested by Park and Wang (2001) in the Chinese context.

Figure 4 Nutrition poverty profile



Source: Authors' calculation based on the CHNS.

Using the specification of Eq. (1), we replaced the nutrient intake with an array of FGT-class indicators: the dummy variable which takes one if the household per capita equivalent total energy intake per day is less than 2,100 kcal and 0 otherwise (FGT(0)); the gap between the household per capita equivalent total energy intake per day and 2,100 kcal for those below the 2,100 kcal and 0 otherwise (FGT(1)); and the squared nutrition gap (FGT(2)). Table 6 reports the standard errors for each estimator based on the unbalanced panel for urban and rural households, respectively.

Table 6 Determinants of the FGT-class nutrition poverty

	Urban			Rural		
	FGT(0)	FGT(1)	FGT(2)	FGT(0)	FGT(1)	FGT(2)
	(1)	(2)	(3)	(4)	(5)	(6)
Income						
Ln(Household per capita net income equivalent adult)	-0.051 (0.044)	-0.019 (0.013)	-0.013 (0.007)*	0.080 (0.043)*	0.010 (0.008)	0.001 (0.003)
Household demographics						
Age cohort (30≤average age<40)	-0.029 (0.056)	0.014 (0.013)	0.010 (0.007)	0.012 (0.037)	-0.004 (0.006)	-0.001 (0.002)
Age cohort (40≤average age<50)	0.033 (0.066)	0.023 (0.015)	0.012 (0.008)	0.049 (0.044)	0.005 (0.008)	0.002 (0.003)
Age cohort (50≤average age<60)	0.087 (0.071)	0.029 (0.016)*	0.010 (0.008)	0.037 (0.054)	0.001 (0.010)	0.001 (0.003)
Age cohort (average age≥60)	0.164 (0.087)*	0.053 (0.021)**	0.018 (0.011)	0.059 (0.065)	0.008 (0.013)	0.003 (0.005)
Proportion of adults	0.107 (0.076)	0.013 (0.018)	0.005 (0.009)	-0.028 (0.060)	-0.013 (0.011)	-0.007 (0.004)*
Gender	-0.069 (0.060)	-0.012 (0.017)	0.001 (0.008)	-0.087 (0.066)	-0.011 (0.012)	-0.0004 (0.004)
Ethnicity	-0.005 (0.116)	0.002 (0.040)	-0.002 (0.024)	0.218 (0.143)	0.044 (0.026)*	0.019 (0.015)
Education	0.008 (0.033)	0.005 (0.009)	0.004 (0.004)	-0.043 (0.032)	-0.005 (0.006)	0.00003 (0.002)
Household wealth/living conditions						
Water source	0.021 (0.023)	0.007 (0.005)	0.003 (0.002)	0.030 (0.019)	0.004 (0.004)	0.002 (0.001)
Toilet type	0.005 (0.017)	0.004 (0.005)	0.002 (0.002)	0.003 (0.011)	0.001 (0.002)	-0.0002 (0.001)
Cooking fuel	-0.009 (0.018)	0.0003 (0.005)	-0.00002 (0.002)	0.013 (0.009)	0.002 (0.002)	0.0001 (0.001)
Household labour						
Out-migration				-0.073 (0.033)**	-0.011 (0.007)	-0.003 (0.003)
Local off-farm				-0.102 (0.041)**	-0.013 (0.007)*	-0.002 (0.003)
Occupation physical activity						
Labourer	0.013 (0.056)	0.010 (0.015)	0.007 (0.008)			
Farmer				-0.068 (0.057)	-0.008 (0.011)	0.001(0.004)
Health						
Illness	-0.002 (0.024)	0.004 (0.007)	0.004 (0.004)	-0.010 (0.020)	-0.003 (0.004)	-0.001 (0.002)
Insurance	-0.012 (0.043)	0.007 (0.013)	0.008 (0.007)	-0.007 (0.025)	-0.001 (0.005)	-0.001 (0.002)
Level of food price						
Cereals	0.619 (1.189)	-0.107 (0.296)	-0.146 (0.140)	0.087 (1.009)	-0.265 (0.195)	-0.117 (0.081)
Fat and oil	-0.240 (0.387)	0.0002 (0.100)	-0.022 (0.049)	-0.896 (0.332)***	-0.216 (0.068)***	-0.066 (0.028)**
Meat	2.112 (1.145)*	0.464 (0.288)	0.238 (0.137)*	0.992 (0.966)	0.511 (0.195)***	0.221 (0.082)***
Eggs	0.046 (0.908)	0.162 (0.243)	0.143 (0.123)	-3.076 (0.828)***	-0.414 (0.163)**	-0.082 (0.066)
Vegetables	-0.318 (0.572)	-0.271 (0.149)	-0.150 (0.075)**	-0.023 (0.513)	-0.082 (0.095)	-0.045 (0.036)
Volatility of food price						
Cereals	0.979 (1.726)	0.682 (0.444)	0.310 (0.223)	-1.803 (1.418)	0.105 (0.283)	0.170 (0.116)
Fat and oil	1.634 (1.070)	0.393 (0.274)	0.108 (0.132)	1.131 (0.789)	0.364 (0.169)**	0.140 (0.074)*
Meat	-3.121 (1.641)*	-0.305 (0.454)	-0.073 (0.232)	-7.286 (1.737)***	-1.247 (0.340)***	-0.291 (0.132)**
Eggs	-3.486 (3.267)	-0.671 (0.841)	-0.428 (0.410)	0.231 (2.012)	-0.015 (0.416)	0.061 (0.172)
Vegetables	-0.129 (0.742)	0.181 (0.215)	0.172 (0.114)	0.496 (0.621)	0.250 (0.117)**	0.100 (0.046)**
Food knowledge						
Chinese diet knowledge	-0.031 (0.025)	-0.010 (0.006)	-0.002 (0.003)	-0.038 (0.024)	-0.005 (0.005)	-0.001 (0.002)
Culture and preference						

Diet preference	-0.029 (0.021)	-0.007 (0.005)	-0.003 (0.003)	0.008 (0.016)	0.001 (0.003)	0.0002 (0.001)
Activity preference	0.004 (0.018)	0.001 (0.005)	0.001 (0.002)	-0.007 (0.014)	-0.003 (0.003)	-0.002 (0.001)
Community						
Population density	0.023 (0.019)	-0.0003 (0.005)	-0.002 (0.002)	0.003 (0.016)	-0.003 (0.003)	-0.001 (0.001)
Transport	-0.005 (0.007)	-0.0004 (0.002)	-0.0003 (0.001)	-0.008 (0.005)*	-0.002 (0.001)**	-0.001 (0.0004)**
Health services	0.005 (0.007)	0.00004 (0.002)	-0.0002 (0.001)	0.004 (0.005)	-0.001 (0.001)	-0.0005 (0.0004)
Social services	-0.009 (0.005)**	-0.002 (0.001)	-0.001 (0.001)	-0.004 (0.005)	-0.003 (0.001)***	-0.001 (0.0004)***
Traditional market	0.018 (0.005)***	0.005 (0.001)***	0.001 (0.0007)**	0.006 (0.003)*	0.002 (0.001)***	0.001 (0.0002)***
Modern market	0.013 (0.007)*	0.002 (0.002)	0.0002 (0.001)	0.001 (0.005)	0.001 (0.001)	0.001 (0.001)
Economy	-0.004 (0.006)	0.0003 (0.002)	0.0002 (0.001)	-0.002 (0.005)	-0.002 (0.001)**	-0.001 (0.0004)***
Provincial dummy	Yes	Yes	Yes	Yes	Yes	Yes
Wave dummy	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	2,469	2,469	2,469	4,066	4,066	4,066
LM statistic for the underidentification test (*p*-value)	8.48 (0.014)	8.48 (0.014)	8.48 (0.014)	10.76 (0.005)	10.76 (0.004)	10.76 (0.005)
F-statistic for the weak identification (*p*-value)	4.27 (0.014)	4.27 (0.014)	4.27 (0.014)	5.41 (0.005)	5.41 (0.005)	5.41 (0.005)
Sargan Chi-/Hansen J statistic for the overidentification test (*p*-value)	0.002 (0.969)	0.38 (0.540)	0.69 (0.405)	0.98 (0.323)	0.54 (0.521)	0.95 (0.264)

Note: ***, **, and * denote 1%, 5%, and 10% significance levels in turn. Heteroscedasticity-robust errors are in parentheses.

Despite positive impact of income on nutrient intake for urban households in Table 2, income growth does not exhibit a statistically significant impact on reducing the incidence of nutrition poverty or narrow the nutrition poverty gap (Columns 1 and 2 of Table 6). It only alleviates the severity of nutrition deprivation (Column 3 of Table 6) because it reduces the inequality of nutrient intake among households by increasing consumption of carbohydrates and protein for the least nourished (Columns 4 and 7 of Table 4). By contrast, a 1% increase in income growth would add 0.08% to the probability of falling below the nutrition poverty line for rural households (Column 4 of Table 6). This is consistent with the negative impact of income on total calorie intake which is likely to be caused by lower protein consumption when the household becomes rich (Column 1 and 4 of Table 3). Neither depth nor severity of rural nutrition poverty could be addressed by income growth, which is broadly consistent with the limited income effects for the least nourished, as found in Table 5.

In order to check the robustness of the above findings, we also re-estimated Table 6 by using a higher nutritional poverty line at 2,400 kcal per person per day as recommended by Park and Wang (2001). The estimated coefficients of income become statistically significant at the 10% level: 1% of income growth can reduce the likelihood of nutrition poverty by 0.103 percentage points and alleviate the nutrition poverty gap and its square by 0.027 and 0.015, respectively, in urban areas. This raises a serious concern about the income-nutrition traps for the least nourished urban households, as the 'nutritional bonus' of income growth has not been shared by the poorest but only approached as far as 'the not-so-poor'. Although income growth increases consumption of carbohydrates and protein for the least nourished households (Table 4), this effect *per se* is not large enough to allow households to escape nutrition poverty. For rural households, the nutrition-poverty increasing effect of income is enhanced to 0.146 at the 5% significance level for FGT(0) under this higher cut-off, and further extends to FGT(1): its estimated coefficient becomes larger (0.023) and significant at the 10% level. This is not unexpected (Figure 1), as richer rural households record lower nutrient intake due to lower carbohydrate consumption.

Aging in urban areas is associated with higher probability for nutritional deficiency, as can be observed by the statistically significant and positive coefficient estimates for those above 50 years and those in retirement age or above 60 years with the coefficient for the latter much higher (Columns 1 and 2 of Table 6).[19] For instance, those in retirement age are 16.4% more likely to be in nutritional poverty. Again, education does not contribute to alleviating nutrition poverty in either urban or rural areas. Ethnic difference surfaces in rural areas: among the nutrition poor, ethnic minorities tend to sink further into the mire than the rest.

Urban households' nutrition poverty responds positively to rising meat prices (Columns 1 and 3 of Table 6), which is expected as meat is a normal good (Table 2). This poverty-increasing effect is also observed for rural households. However, in this case, nutritional poverty is more negatively related with higher prices of 'fat and oil' and eggs (Columns 4-6 of Table 6), which is consistent with Table 3.

The community development in terms of better transport, social services and economic prosperity helps combat rural nutrition poverty (Columns 4-6 of Table 6), while urban households seem to only benefit from social services in reducing the incidence of nutritional deprivation. Neither traditional nor modern markets development exhibits poverty-reducing effects, but rather deteriorates the nutritional status.

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[19] This still holds under the nutrition poverty line of 2,400 kcal per person per day.

5. Conclusion

This study has examined a number of factors in determining Chinese households' nutrient intake over two decades (1989-2009). A point of departure of the present study is to model (i) heterogeneity in the effect of household income and nutritional intake, and (ii) the endogeneity of household income to provide a robust estimate for the effect of income on nutrition at different levels of nutritional intake. To do this, we have proposed to combine recent seminal works by Canay (2011) and Lee (2007) to estimate the quantile instrumental variable (IV) panel model.

Income growth, especially stemming from household business and wages, is associated with nutritional improvement of urban rather than rural households. For the latter population, only crop income appears to encourage total energy consumption. [20]

As income keeps rising, those with moderate or higher nutrient intake tend to restrain their further nutrition consumption, especially fat for rural households, and the least nourished tend to consume more carbohydrates and protein. Thus, income growth is likely to reduce nutrition inequality among households. Nevertheless, somewhat surprisingly, education, dietary knowledge or habits of eating and physical exercise seem unimportant for household nutrients' intake. Only the better-nourished in urban areas are able to benefit from widely believed contributors of nutrition intake such as dietary knowledge, local off-farm employment and out-migration. Furthermore, uncertainties in terms of soaring and volatile food prices that have recently been observed all over the world suggest substantial but different effects on household nutrition demand, varying with specific food commodities. It is conjectured that in urban areas, the positive aggregate household income effects on nutrition, or the nutrition-poverty reducing effects of income, are weak and other factors, such as, increases in food price and its volatilities (e.g. meat) and aging, can easily offset the weak income effects, which have resulted in the increase in the proportion of undernourished despite the high income growth of urban households.[21] In rural areas, the aggregate household income effect on nutrition is negative, or increase in household income tends to raise nutrition-poverty. That is, as the average household income goes up, the proportion of undernourished tends to increase unless they have access to out-migration or local off-farm employment, or alternatively, significantly increase the share of crop income in the total income. Overall, the pattern of income growth, the rising food prices and uncertainties attached to them appear to jointly explain the income growth-nutrition reduction paradox in China.

Turning to policy implications, agriculture still plays a key role in improving rural households' nutrition if the policy maker takes advantages of positive loops between income and nutrition. However, policies promoting income growth alone may not be sufficient to raise households' nutrients' intake, as the poor, especially in urban areas where people also face nutrition deficiency because of aging, seem not to enjoy the benefit of income growth. Certain traditional recipes alone, such as promoting education, may not be effective in the Chinese context. Interventions have to be tailored to serve better urban and rural population, respectively. For the former, more pro-(nutrition) poor income growth would enhance nutrient intake and narrow nutrition inequality between households to some

[20] Weak effects of household income or expenditure in improving nutrients have been found in India. Gaiha et al. (2014) have applied the estimation embedded in a standard demand theory framework to the National Sample Survey data in India whereby nutrient demand is a function of assets, prices and demographics. They found that diet diversification has slowed down faster especially in rural areas and this appears to be linked to the weak link between household expenditure and nutrients.

[21] This reflects the weak (though statistically insignificant) elasticity of nutrition poverty headcount with respect to household income whereby even doubling the average household income reduces nutrition poverty only by -5.1%, *ceterus paribus* (Column 1 of Table 6).

extent. For the latter, growth of crop income is of paramount importance. Moreover, community development is also a policy instrument to promote rural households' nutrients' intake. For both urban and rural populations, the policies stabilising income streams and helping cushion against the risks of soaring and volatile prices of food commodities would generate substantial positive impact on household nutrition status.

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Appendix 1: Definition and descriptive statistics of variables

Variable	Definition	No. of obs.	1989		2009	
			Mean	S.D.	Mean	S.D.
Modified OECD equivalent household size	Weighted sum of household members. The first adult in the household has a weight of 1. Each additional adult aged 14 and over has a weight of 0.5. Each child aged under 14 has a weight of 0.3. This definition can be found at Eurostat: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Equivalised_disposable_income [accessed December 5, 2013]	29,402	1.371	0.367	1.328	0.503
Household equivalent per capita net income	Household net income divided by the equivalent household size. Household net income is total income (including agricultural and family business income, wages, transfer income and asset income) minus related costs, taxes and fees. All monetary values are transformed into real terms by dividing them by the spatial CPI calculated by the CHNS team.	29,402	4,967	6,090	20,499	28,219
Household equivalent per capita agricultural income	Household net agricultural income divided by the equivalent household size. Household net agricultural income is the total agricultural income produced by the household net of relevant costs. All monetary values are transformed into real terms by dividing them by the spatial CPI calculated by the CHNS team.	14,042	1,602	2,990	5,206	8,320
Household equivalent per capita business income	Household net business income divided by the equivalent household size. Household net business income is total income from household small business activities net of relevant costs. All monetary values are transformed into real terms by dividing them by the spatial CPI calculated by the CHNS team.	14,042	468.7	2,042	2,870	19,492
Household equivalent per capita wage income	Household wage income divided by the equivalent household size. Household wage income is the sum of individual household members' wages. All monetary values are transformed into real terms by dividing them by the spatial CPI calculated by the CHNS team.	14,042	3,088	5,012	10,064	20,106
Household equivalent per capita total calorie intake	The sum of individual total calories intake within the household, which is calculated by the CHNS team, divided by the equivalent household size. The CHNS team calculated the individual total calories intake as the sum of direct calories intake and the converted amount from carbohydrate, fat and protein. Their conversion rates are from FAO (2003): 1 gram of fat, carbohydrate and protein equals separately 9, 4 and 4 kcal.	29,402	7,200	2,498	5,661	3,085
Household equivalent per capita direct calorie intake	The sum of individual direct calories intake within the household divided by the equivalent household size.	29,402	3,608	1,253	2,844	1,544
Household equivalent per capita calorie intake from fat	The sum of individual calories intake inverted from fat within the household divided by the equivalent household size. According to FAO (2003), 1 gram of fat=9 kcal.	29,402	982.7	742.7	929.9	1,309
Household equivalent per capita calorie intake from carbohydrate	The sum of individual calories intake inverted from carbohydrate within the household divided by the equivalent household size. According to FAO (2003), 1 gram of carbohydrate=4 kcal.	29,402	2,221	856.6	1,544	556.7
Household equivalent per capita calorie intake from protein	The sum of individual calories intake inverted from protein within the household divided by the equivalent household size. According to FAO (2003), 1 gram of protein=4 kcal.	29,402	388.5	148.5	343.7	132.1
Age	Age of household head in years.	29,402	22.059	14.987	41.574	22.143
Gender	Gender of household head, 0=female, 1=male.	29,402	0.636	0.481	0.701	0.458
Ethnicity	Ethnicity of household head, 0=majority (Han), 1=minorities (non-Han).	29,402	0.113	0.317	0.014	0.119
Education	Educational level of household head, i.e., having completed or finished part of the following educational levels. Categorical variable, 0=illiterate, 1=primary education, 2=junior high school, 3=senior high school, 4=higher education.	29,402	6.132	3.993	6.954	4.381
Water source	Categorical variable, 1=natural water (rainfall, ice, snow, creek, spring, lake, and river), 2=open well (depth≤5m), 3=ground water (depth>5m), 4=tap water or water plant.	29,402	3.372	0.851	3.679	0.590
Toilet type	Categorical variable, 0=no toilet, 1=cement or earth openpit, 2=no flush, 3=flush but outside house, public restroom, 4=in-house flush.	29,402	1.640	1.111	2.678	1.420
Cooking fuel	Categorical variable, 1=wood, sticks, straw, charcoal, etc., 2=coal or kerosene, 3=liquified natural gas or natural gas,	29,402	1.890	0.624	2.850	1.038

	4=electricity.					
Out-migration	No. of household members not living in the household and in out-migration.	29,402	2.507	1.117	0.189	0.535
Local off-farm	No. of household members living in the household and have local off-farm jobs.	29,402	0.930	1.081	0.571	0.838
Farmer	Dummy variable, 1=the occupation of household head is 'farmer', 0=otherwise.	29,402	0.257	0.437	0.200	0.400
Illness	Dummy variable, 1=any household member was ill in the last 4 weeks, 0=otherwise.	29,402	0.253	0.435	0.299	0.458
Insurance	Dummy variable, 1=any household member has health insurance, 0=otherwise.	29,402	0.430	0.495	0.959	0.199
Level of food price	Provincial index of real food price, 2009 prices=1.	23,847	0.394[a]	0.023[a]	1	0
Level of cereal price	Provincial index of real cereal price, 2009 prices=1.	23,847	0.373[a]	0.018[a]	1	0
Level of fat price	Provincial index of real fat & oil prices, 2009 prices=1.	23,847	0.494[a]	0.062[a]	1	0
Level of meat price	Provincial index of real meat price, 2009 prices=1.	23,847	0.331[a]	0.043[a]	1	0
Level of egg price	Provincial index of real egg price, 2009 prices=1.	23,847	0.604[a]	0.081[a]	1	0
Level of price of education services	Provincial index of real prices of education, including both tuition fees and other costs relating to obtaining education, 2009 prices=1.	20,503	0.449[b]	0.092[b]	1	0
Level of price of health services & equipment	Provincial index of real prices of health services and health equipment, 2009 prices=1.	16,978	0.948[c]	0.060[c]	1	0
Volatility of food price	Coefficient of variation of the level of food price defined above in a two-year window.	23,847	0.076[a]	0[a]	0.010	0
Chinese diet knowledge	Dummy variable, 1=any household member knows the Chinese diet guidelines (also known as the Chinese diet pagoda), 0=otherwise.	13,140	0.123[d]	0.328[d]	0.199	0.399
Diet preference	Dummy variable, 1=any household member reports 'like' or 'very much like' for fast food, salty snack foods, soft drinks or sugared drinks, 0=otherwise.	11,605	2.370[d]	0.627[d]	2.415	0.579
Activity preference	Dummy variable, 1=any household member reports 'like' or 'very much like' for participation in walking, Tai Chi, sports or body building, 0=otherwise.	10,300	2.771[d]	0.694[d]	2.614	0.603
Population density	Total population of the community divided by community area, from local official records.	29,402	5.871	1.374	5.935	1.489
Transport	Community index reflecting infrastructure: most common type of road; distance to bus stop; and distance to train stop. Distance is categorized as (1) within community, (2) $\leq$1 km from community, and (3) $\geq$ 1 km from community.	29,402	4.431	2.456	5.941	2.184
Health services	Community index reflecting the number and type of health facilities in or nearby ($\leq$12 km) the community and number of pharmacies in community.	29,402	6.061	1.884	5.932	2.559
Modern market	Community index reflecting the number of supermarkets, cafes, internet cafes, indoor restaurants, outdoor fixed and mobile eateries, bakeries, ice cream parlours, fast food restaurants, fruit and vegetable stands, bars within the community boundaries.	29,402	4.080	3.007	4.328	2.893
Traditional market	Community index reflecting the distance to three market categories; (1) within the boundaries of the community, (2) within the city but not in this community, or (3) not within the city/village/town); the number of days of operation for eight different types of market (including food and fuel markets).	29,402	4.976	3.032	4.839	3.468
Economy	Community index reflecting typical daily wage for ordinary male worker (reported by community official) and per cent of the population engaged in non-agricultural work.	29,402	3.075	1.767	6.611	3.236
Urban	Dummy variable, 0=rural areas, 1=urban areas.	29,402	0.397	0.489	0.321	0.467

Source: Authors' calculation based on the CHNS. Provincial data on average wages, various prices and natural disasters are authors' calculation and compilation based on data from China Statistical Yearbooks published annually by the NBS. Urbanisation indices for the communities where sample households locate were constructed by Jones-Smith and Popkin (2010) and compiled into the CHNS dataset by the CHNS team. Relevant indices include the population density, transport, health services, modern market, traditional market and economy.

Note: a. Data have been collected since 1993.

b. Data have been collected since 1997.

c. Data have been collected since 2000.

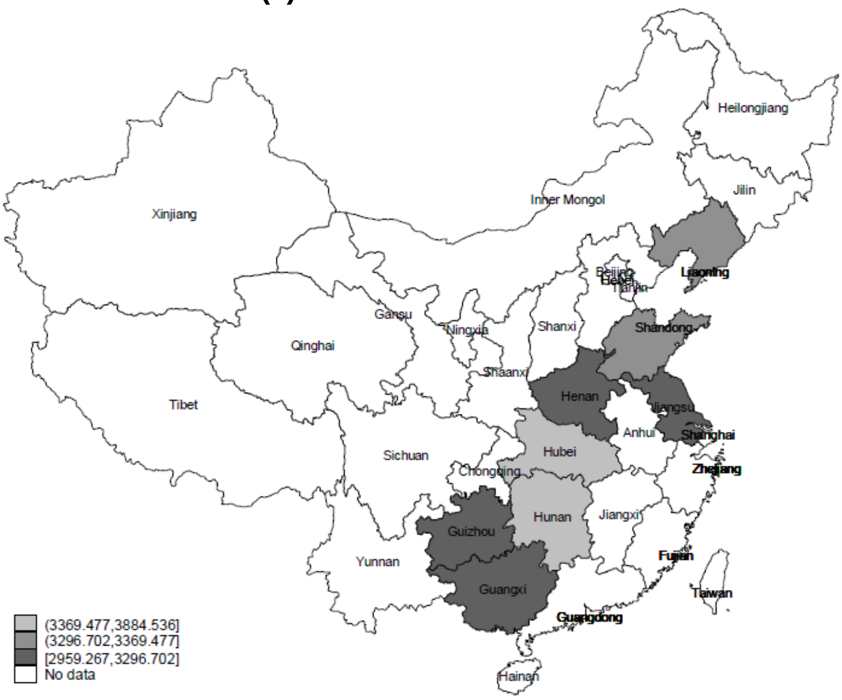
d. Data have been collected since 2004.

Appendix 2: Further Data Analyses

By plotting provincial intertemporal mean household nutrient intake in Figure A1, we further document a spatial pattern of nutrition status in China. If we focus on urban areas (Figures 4(a) and 4(b)), provinces in northeast and southwest regions in China show consistently the lowest nutrition status over time, as opposed to economically advanced regions near the coast, such as Jiangsu, Shandong and Henan, which used to be the least nourished in 1989 but have experienced the highest nutrient intake by 2009. Similar pattern can also be observed in rural areas (Figures 4(c) and 4(d)), except Guizhou, showing the overall positive correlation between income and nutrition at province levels. This appears to contradict with the aforementioned negative nexus between income and nutrition at the household level, giving rise to our conjecture of substantial heterogeneity in the impact of income on nutrition and thus, making our quantile estimation necessary. One may also note that Guizhou, which is the poorest province in terms of real GDP per capita among all provinces over the past three decades, had high initial nutrition level, which ranked 3rd in 1989 among all sample provinces (3,773 kcal per household equivalent adult per day), but recorded the largest reduction in the following waves (1,280 kcal between 1989 and 2009) as a result of the highest increases in living costs (measured by the spatial consumer price index) in all sample provinces.[22]

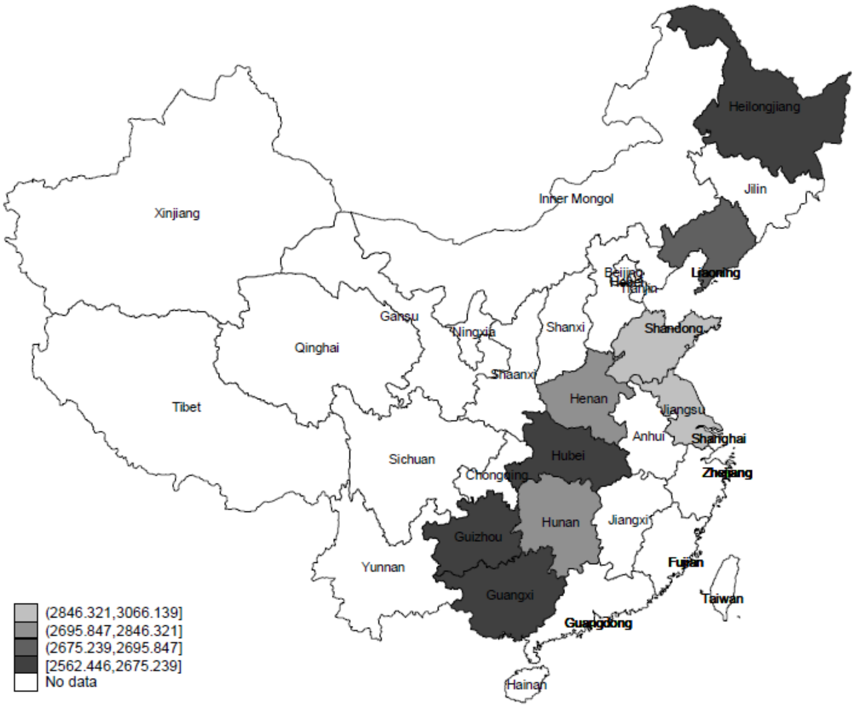
Figure A1 The 'hunger' map of China (1989-2009)

(a) Urban areas in 1989

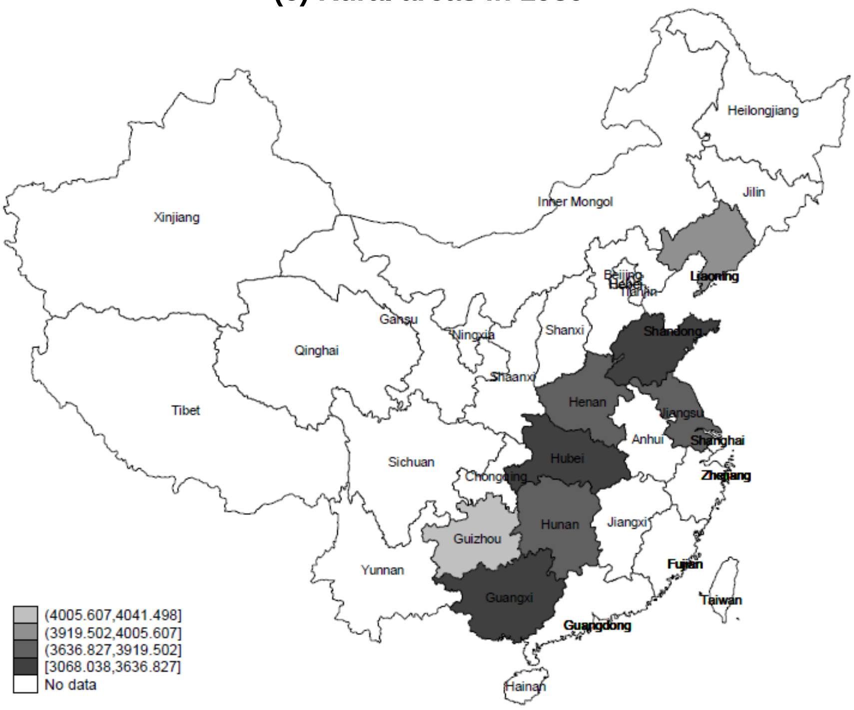


(b) Urban areas in 2009

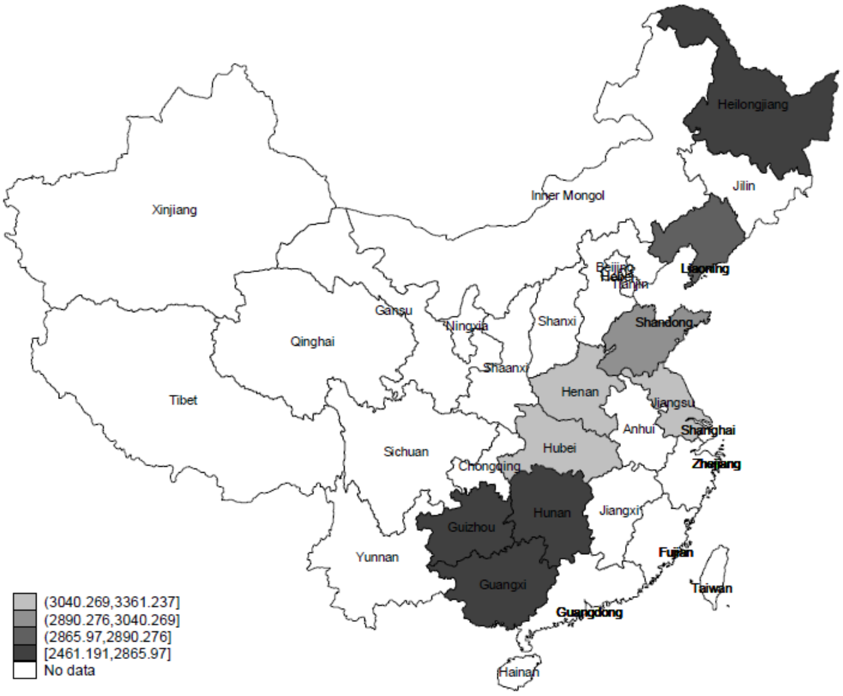
[22] The CHNS team constructed a spatial consumer price index for sample provinces, which is comparable across all sample provinces and over time. The prices in Guizhou saw the highest increases (three-fold) in all sample provinces.



(c) Rural areas in 1989



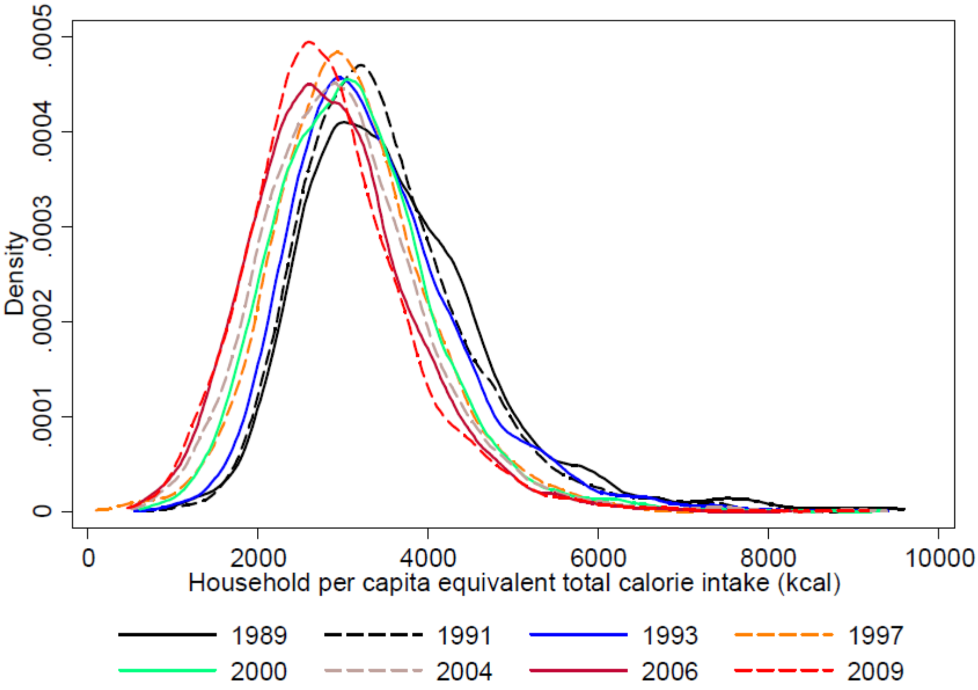
(d) Rural areas in 2009



Note: The provincial average nutritional status is measured as the average household per capita equivalent total energy intake (kcal) per day for each sample province in each year.
Source: Authors' calculation based on the CHNS.

FAO's SOFI 2013 reports a declining trend in undernourishment in China. The proportion of the undernourished in total population has declined from 22.9% in 1990-1992 to 11.4% in 2011-2013 (FAO, 2013). Their methodology assumes a constant probability distribution of individual daily dietary energy consumption, while Figure A2 demonstrates obviously changing distribution over time. See, for instance, de Haen et al. (2011) and de Weerdt et al. (2014) for the detailed critiques of the FAO methodology.

Figure A2 Distribution of household energy intake



Source: Authors' calculation based on the CHNS.