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RESEARCH ARTICLE

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The Demand for Nutrients in China

Abstract China is experiencing a nutritional transition accompanied by its rapid economic growth. However, the relationship between income growth and nutritional improvement is still unclear. In contrast with the biased indirect method, this paper employs a direct method to estimate the income elasticities of 22 nutrients using household survey data to fill the gap in the current literature. Our results indicate that the income elasticities of most nutrients are smaller than that which is stated in the current literature using the indirect method, and vary for different income groups.

Keywords nutrients, income elasticity, nutritional improvement, China
JEL Classification D12, O53, Q10

1 Introduction

Coinciding with its rapid economic growth, the structure of food consumption in China has changed drastically (Popkin, 1993, 2001; Dremnowski and Popkin, 1997; Du et al., 2002; Huang and Gale, 2009; Yu and Abler, 2009; Gao et al., 2013). The current literature finds that more and more Chinese consumers are switching from low-fat traditional food, mainly based on cereals and vegetables with few animal products, to a western-style diet which is high in saturated fat and sugar, but low in fiber (Popkin, 1993, 2001; Guo et al., 2000; Du et al., 2002; Gale and Huang, 2007). Accordingly, the demand for different nutrients is also significantly changing. Zhai et al. (2009) found that fat becomes a more important source of energy in an adult's diet, while the proportion of energy derived from carbohydrates quickly declines. Meng et al. (2009) indicates that

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calories obtained from cereal products have been declining over time, which has been compensated by a sharp increase in fruit and vegetable consumption. In addition, Huang and Gale (2009) measure nutrient availability for urban consumers at different income levels, and their results indicate that both shares of protein and fat in energy intake and the availability of most minerals, except for iron, manganese, and vitamins are increasing with rising income.

The effects of economic growth on malnutrition have attracted a lot of concern (Ravallion, 1990). Broadly speaking, income can influence nutrient intake in two ways: by affecting the quantity of nutrients consumed, and affecting the sources of nutrients (Ye and Taylor, 1995). However, to what extent nutrition responds to income, and to what extent hunger and malnutrition can be eliminated by economic growth, are still controversial (Behrman and Deolalikar, 1987; Ravallion, 1990; Ye and Taylor, 1995; Subramanian and Deaton, 1996; Gibson and Rozelle, 2002; Skoufias et al., 2009). Empirical studies have revealed contradictory results with regard to the income elasticity of nutrient demand. For instance, Behrman and Deolalikar (1987) propose that the real nutrient elasticities with respect to income may be close to zero in rural south India, so that an increase in income will not lead to a substantial improvement in nutrient intake. Bouis and Haddad (1992) also found that income elasticity fell in the range between 0.08 and 0.14 through the use of direct recall survey data in the Philippines. Moreover, Pitt and Rosenzweig (1985) also report very low (below 0.03) income elasticities for many nutrients in Indonesia. On the other hand, some literature asserts that income elasticities are much larger than zero. According to the study of Ravallion (1990) in Indonesia, the income elasticity of calorie demand at the mean point can considerably understate the prevalence of caloric under-nutrition, and in particular, the elasticity can rise from 0.15 to 1.5 after controlling all variations in non-budgetary variables. Similarly, Subramanian and Deaton (1996) found that in rural Maharashtra, India, the calorie elasticity with respect to total expenditure is between 0.3 and 0.5. In addition, Gibson and Rozelle (2002) found that in urban Papua New Guinea, the unconditional calorie demand elasticity is about 0.6 for the poorest half of the population, and they further confirmed this finding in nonparametric and semiparametric estimations.

Only a few papers have researched the demand for nutrients with respect to income in China. Ye and Taylor (1995) used a structural model to control the endogeneity of nutrient costs, finding that the income elasticities of calorie intake and protein intake are high in low-income rural households but decline rapidly as income grows. Meng, Gong, and Wang (2009) also found that the income elasticity of calorie consumption is more than 0.5 for the low-income group in urban China and declines with rising income. However, these studies only focus on macronutrients. Micronutrients such as minerals and vitamins, which are also very important in metabolism and perform specific functions for promoting growth, reproduction, and the maintenance of health and vitality, are not well studied even though micronutrient malnutrition is a widespread problem in developing countries (Qaim et al., 2007; Skoufias et al., 2009). An exception in the literature is found in Huang and Gale (2009) who calculated the income elasticities for 28 nutrients by converting the food demand elasticities to nutrient elasticities with use of information given by unit nutrient values for foods. Their results showed that most nutrient elasticities with respect to income are from 0.1 to 0.5 for the lowest quartile income group in urban China; this elasticity eventually drops to less than 0.2 for the other three quartiles. However, the method they use, of first estimating the food demand elasticities with respect to income for highly aggregated food categories and then converting these elasticities to nutrient elasticities with respect to income by using a fixed food-nutrient conversion matrix, is biased if there is strong substitution within food groups (Behrman and Deolalikar, 1987).

Therefore, it is necessary to re-estimate the income elasticities of all nutrients with a different methodology particularly in the context of rapid economic growth and changing dietary patterns in China. It is also quite important to know how nutrient intake changes with income and whether successful economic growth substantially improves the nutritional status of the Chinese people, which has strong implications for public policy aiming at malnutrition alleviation. Moreover, it can also provide some implications for the increasing prevalence of diet-related, non-communicable disease (DR-NCD), such as obesity in China. The current literature (e.g., Popkin, 2001; Du et al., 2002) finds that large shifts toward a high-fat diet and increased inactivity are consistent with the rapid increase of child and adult obesity, and they are causally linked in some cases. Therefore, following the suggestion of Behrman and Deolalikar (1987), we estimate the income elasticities of 22 nutrients in a reduced-form model by using household survey data, which will lead to more reasonable results for income elasticities of nutrients and will provide better nutritional policy implications in the context of rapid economic growth.

In the rest of this paper, we first develop an econometric model following the methods used by Behrman and Deolalikar (1987), Ye and Taylor (1995) and Subramanian and Deaton (1996), and then introduce the data and estimate the income elasticities of nutrients. Finally, we draw a brief conclusion.

2 Methodology

Following the pioneering work of Lancaster (1966), nutrients are viewed as attributes of food consumption, resulting in the consumers' choice problem of maximizing the utility function of food subject to a budget constraint as shown by a set of transformation equations that link nutrient availability to food consumption. However, Huang (1996, 1999) argues that this approach is rather difficult to implement empirically because a nonlinear programming problem has to be solved to obtain the nutritional implication of food consumption, and it is also difficult to define a proper functional form for the utility function. Thus, the current literature usually measures nutrient availability by way of food demand.

Food expenditure usually rises as income increases, and lower-income groups have higher food expenditure elasticities with respect to income (Ye and Taylor, 1995). However, an increase in food expenditure does not necessarily result in higher nutrient intake. A number of studies have already shown that consumers care less about nutrition and more about other food attributes such as taste, appearance, status, convenience, degree of processing and variety as they become richer, so that an increase in income may not necessarily lead to a healthier diet (e.g., Behrman and Deolalikar, 1987; Behrman et al., 1988; Ye and Taylor, 1995; Gao et al., 2013; Jensen and Miller, 2010). These non-nutritive qualities are not necessarily positively correlated with the nutritive value (Ye and Taylor, 1995), but the unit cost of nutrients will change dramatically with the consumers' preference even though the nutrient intake might not change so much. Therefore, high food expenditure elasticity with respect to income can coexist with low income elasticity for a certain nutrient intake (Behrman and Deolalikar, 1987; Behrman et al., 1988).

In estimating the income elasticity of nutrient intake, two econometric approaches are commonly used. The first one is an indirect approach, in which food demand systems for a relatively small number of food categories are estimated in a structural model and the nutrient elasticities are then derived from food elasticities by using a constant nutrient-to-food conversion factor (e.g., Huang, 1996, 1999; Huang and Gale, 2009). The other approach is a reduced-form model advocated by Behrman and Deolalikar (1987), in which total nutrient intake converted from detailed food consumption data is regressed directly on income or food expenditure. To demonstrate the difference between these two approaches, we derive the nutrient elasticity with respect to income following Behrman and Deolalikar (1987), Ye and Taylor (1995) and Subramanian and Deaton (1996) as follows:

N_k is defined as the total intake of nutrient k (e.g., calorie, protein).

$$N_k = \sum_i C_{ki} * F_i \,, \quad (1)$$

where C_{ki} is the average content of nutrient k in one unit of food group i; F_i is the quantity consumed of food group i. All of these three variables are related to income, thus we can take the logarithm on both sides of Eq. (1) and differentiate with respect to the logarithm of income M, then the income elasticity of nutrient k can be written as:

$$\varepsilon_{N_k M} = \sum_i S_{ki} * \varepsilon_{F_i M} + \sum_i S_{ki} * \varepsilon_{C_{ki} M} , \tag{2}$$

$$S_{ki} = \frac{N_{ki}}{N_k} = \frac{C_{ki} * F_i}{\sum_i C_{ki} * F_i} , \tag{3}$$

where ε_{XY} is the elasticity of X (N_k, F_i and C_{ki}) with respect to $Y(M)$, N_{ki} is the intake of nutrient k from food i, and S_{ki} is the share of total intake of nutrient k obtained from food group i. As aforementioned, the indirect approach estimates the nutrient elasticity by converting the food elasticity using a food-to-nutrient conversion factor (e.g., Huang, 1996, 1999), which implicitly assumes that the second term in the right side of Eq. (2) is zero. The implication of this assumption is that the average contents of every nutrient in each food group are constant. Regarding the high level of aggregation in food demand systems, this is definitely not the case in practice. Yu and Abler (2009) proposed that food quality increases with income, and it hence would be true that average nutrient contents, as an index of quality, would certainly change with income.

Furthermore, we are more concerned with the relationship between food expenditure elasticity with respect to income and the nutrient elasticity with respect to income. Thus we continue our deductions as follows:

$$E_i = F_i * P_i , \tag{4}$$

where E_i is the expenditure on food group i, and P_i is the average price. From Eq. (4) we can easily estimate food expenditure elasticity with respect to income as follows:

$$\varepsilon_{E_i M} = \varepsilon_{F_i M} + \varepsilon_{P_i M} , \tag{5}$$

or

$$\varepsilon_{F_i M} = \varepsilon_{E_i M} - \varepsilon_{P_i M} , \tag{6}$$

Substituting Eq. (6) into Eq. (2) yields:

$$\varepsilon_{N_k M} = \sum_i S_{ki} * \varepsilon_{E_i M} + \sum_i S_{ki} * \varepsilon_{C_{ki} M} - \sum_i S_{ki} * \varepsilon_{P_i M} . \tag{7}$$

We then define the average cost of nutrient k obtained from food group i as q_{ki}, so that the mean price of food group i can be written as:

$$P_i = \frac{q_{ki} * C_{ki}}{\theta_{ki}} , \tag{8}$$

where θ_{ki} denotes the contribution share of nutrient k to the price of food group i, so that:

$$q_{ki} = \frac{P_i * \theta_{ki}}{C_{ki}} . \tag{9}$$

Similarly, taking the logarithm of Eq. (9) and differentiating it with respect to the logarithm of income we get:

$$\varepsilon_{q_{ki}M} = \varepsilon_{P_iM} + \left(\frac{d \ln \theta_{ki}}{d \ln C_{ki}} - 1 \right) * \varepsilon_{C_{ki}M} . \tag{10}$$

Usually, θ_{ki}, the contribution share of nutrient k to the price of food group i is taken as an exogenous variable, as done by the current literature (e.g., Behrman and Deolalikar, 1987; Ye and Taylor, 1995; Subramanian and Deaton, 1996; Gibson and Rozelle, 2002; Skoufias et al., 2009), so that we have $\frac{d \ln \theta_{ki}}{d \ln C_{ki}} = 0$. Then Eq. (10) becomes:

$$\varepsilon_{q_{ki}M} = \varepsilon_{P_iM} - \varepsilon_{C_{ki}M} . \tag{11}$$

The income elasticity of nutrient k can be written as follows by combining Eq. (7) and Eq. (11).

$$\varepsilon_{N_kM} = \sum_i S_{ki} * \varepsilon_{E_iM} - \sum_i S_{ki} * \varepsilon_{q_{ki}M} . \tag{12}$$

The indirect approach effectively assumes that the second term in the right side of Eq. (12) is zero; however this is not the case in practice. Behrman and Deolalikar (1987) indicate that the elasticity of the average cost of a nutrient within a food group with respect to total expenditure is usually positive. Thus, nutrient elasticity with respect to income estimated by the indirect approach with a high level of aggregation is overestimated and larger than the direct estimates based on more detailed food data. For instance, Huang (1996) finds that all 15 nutrient elasticities with respect to income are higher than 0.2 in the United States, which could be overestimated.

Behrman and Deolalikar (1987) also point out that if there are possible intra-food substitutions within specific food groups, the direct nutrient elasticity might be slightly upwardly biased. This bias however could be neglected if the number of food categories is very large. For instance, there are more than 1,500 food categories in our data, so that the intra-food substitution should be quite limited. Therefore, the direct approach is proposed here.

After converting the food consumption into nutrient intake, a straightforward econometric model is proposed as follows:

$$\ln N_k = \beta_0 * \ln M + \sum_j \beta_j * Z_j + u, \tag{13}$$

where Z_j denotes all control variables, including household size, and the proportion of people in each specific age-gender cohort, which are often used in empirical studies (e.g., Behrmand and Deolalikar, 1987; Ye and Taylor, 1995; Subramanian and Deaton, 1996; Deaton, 1997). The average education level of the family members who cooked in the past week, and the knowledge of nutrition, represented by a dummy (which is one if any adult in the family has ever heard about the Chinese Pagoda or the Dietary Guidelines for Chinese Residents and zero otherwise), are also included in our model, because they might be related to the types of food household members have consumed and the way in which people cook (Strauss and Thomas, 1998).

Finally, to control the price effect and the unobservable non-price community endowments, we use a dummy variable for each community, as suggested by Behrman and Deolalikar (1987). There is little price variation for a nutrient within a community in the context of cross-sectional data, and hence the regional dummy is sufficient to capture spatial price variations (Deaton, 1988). Given the non-substitutable nature of micro-nutrients, the cross-price elasticities should theoretically be equal to zero. Hence, we do not need to include the price information in the econometric model (13).

3 Data

The data used in this paper are taken from the China Health and Nutrition Survey (CHNS), collected by the Carolina Population Center at the University of North Carolina at Chapel Hill, the Institute of Nutrition and Food Hygiene and the Chinese Academy of Preventative Medicine. Data from the 2004 survey is used in this paper, as this is the only year for which we have obtained price information. The sample contains data from around 4,000 households utilizing a multi-stage, random cluster strategy for 9 provinces (Liaoning, Heilongjiang, Jiangsu, Shandong, Henan, Hubei, Hunan, Guangxi, and Guizhou). Details on household food consumption (more than 1,500 food categories) was collected for three consecutive days, which are randomly allocated from Monday to Sunday, and calculated by the changes in food inventory from the beginning to the end of this period. On the other hand, data on individual dietary intake (24-h recall) both away from home and at home and the number of meals eaten at home for the same three consecutive days were also collected for all family members (Guo et al., 2000; Du et al., 2002; Popkin et al., 2002; Wang et al., 2002; Du et al., 2004). In the end, a weighted method is used to calculate food consumption on a per person per day basis. A detailed explanation to the data is provided in the appendix.

We primarily assume food is symmetrically allocated among all members within a household, and generate the per capita food consumption for each household. The heterogeneities regarding gender, age and other household characteristics can be controlled in econometric analysis to represent the discrimination in intra-household allocation mentioned in previous studies (Strauss and Thomas, 1998; Mangyo, 2008; Shimokawa, 2010). More explanations to the data source and conversion methods can be seen in the

Appendix.

A descriptive statistic of nutrient intake after dropping all outliers (we will discuss this in the next section) and the corresponding dietary reference intake (DRI) are shown in Table 1. We find that the average daily per capita calorie intake in China is around 2,224 kilocalories, a little lower than the Chinese Dietary Intake (RNI) level for female working people with medium labor intensity. This is reasonable since the sample in this survey contains not only working people, but also children and old people who have lower energy requirements. The shares of calorie intake from protein, fat and carbohydrates are 11.70%, 30.89% and 57.41%, respectively, which all fall in the suggested ranges. However, protein only accounts for a very small proportion, implying the low level of protein consumption in the Chinese diet. The intake of edible fiber is less than half of the DRI for adults, which might be partly caused by the low content of fiber in the diet for children and old people.

Moreover, we find that Chinese people consume more than twice the amount of fat-soluble vitamins as recommended, such as vitamin A and vitamin E, but less water-soluble vitamins than the suggested levels for adults, such as vitamin B1, vitamin B2 and vitamin C, which indicates that vitamin deficiency is still quite prevalent in China, because the latter must be consumed more regularly (1–3 days) to meet the body's need, while the former can be taken in large amounts once in a while (weeks or even months) and still meet the body's requirement over time (Whitney and Rolfes, 2005).

As for minerals, the intake of calcium, potassium, magnesium, zinc and selenium are lower than the DRI levels for adults, but the intake of phosphorus, sodium, iron, copper and manganese surpass the recommended level. In particular, the intake of sodium is almost three times of the DRI level and substantially exceeds the upper level recommended by the Food and Nutrition Board (FNB) in 1989, implying a severely excessive intake of sodium in China, which has been announced by the Chinese Nutrition Society (CDC, 2002). In addition, we also summarize the average nutrient intake for families below and above the international poverty line ($2 per day), respectively. The statistics show that families above the poverty line have a higher intake of energy than the families below the poverty line, and they consume more calories from protein and fat, but less from carbohydrates, which is consistent with previous studies showing that there is a rising concern about obesity because of the increasing intake of fat in rich families (Popkin, 1993, 2001; Guo et al., 2000; Du et al., 2002; Gale and Huang, 2007). Moreover, we also find that rich families have a higher intake of cholesterol, vitamins (vitamin A, B1, B2, B3, C and E) and most minerals (calcium, phosphorus, potassium, magnesium, sodium, iron, zinc, selenium, and copper). The results are also shown in Table 1.

Table 1 Nutrient Intake and Dietary Reference Intake

Nutrients	Average intake		Poverty line		DRI			Unit
	Obs.	Mean	Below	Above	Adult male	Adult female	UL	
Energy	3,433	2,224	2148	2,259	2,700	2,300	N.A.	kcal
Protein	3,433	65.75	60.44	68.15	0.1–0.35	0.1–0.35	N.A.	g
Fat	3,433	77.15	64.60	82.80	0.2–0.35	0.2–0.35	N.A.	g
Carbohydrate	3,433	322.65	337.00	316.19	0.45–0.65	0.45–0.65	N.A.	g
Fiber	3,433	11.21	11.43	11.11	24	24	N.A.	g
Cholesterol	3,433	272.41	187.14	310.82	NA	NA	N.A.	mg
Vitamin A	3,433	1,601.74	1,530.26	1,633.93	800	700	3,000	ugRE
Thiamin-B1	3,433	0.99	0.98	1.00	1.4	1.3	50	mg
Riboflavin-B2	3,433	0.76	0.66	0.81	1.4	1.2	N.A.	mg
Niacin-B3	3,433	14.05	13.24	14.42	14	13	35	mgNE
Vitamin C	3,433	86.79	84.99	87.60	100	100	1,000	mg
Vitamin E	3,433	34.95	31.08	36.69	14	14	800	mg
Calcium	3,433	393.32	351.36	412.21	800	800	2,000	mg
Phosphorus	3,433	972.62	941.41	986.68	700	700	4,000	mg
Potassium	3,433	1,608.37	1,511.08	1,652.19	2,000	2,000	N.A.	mg
Magnesium	3,433	304.24	297.04	307.48	350	350	N.A.	mg
Sodium	3,433	5,993.14	5,850.15	6,057.54	2,200	2,200	2400	mg
Iron	3,433	21.86	21.34	22.09	15	20	50	mg
Zinc	3,433	10.84	10.37	11.05	15.5	11.5	45/37	mg
Selenium	3,433	40.20	35.07	42.50	50	50	400	ug
Copper	3,433	2.02	1.97	2.04	2	2	8	mg
Manganese	3,433	6.50	6.87	6.33	3.5	3.5	10	mg

Note: (1) Nutrient intake denotes the real nutrient intake generated from household survey data. DRI denotes the dietary reference intake suggested by the Chinese Nutrition Society (2000). UL denotes the upper level and N.A. refers to not determined.

(2) The energy is derived from the protein, fat, carbohydrate, and alcohol content of the food consumed using 4, 9, 4 and 7 as conversion factors, respectively. The DRI levels for protein, fat and carbohydrates are the acceptable macronutrient distribution ranges (AMDR).

(3) The content of carbohydrates in 100g of food is estimated as: carbohydrates= 100–(water + protein + fat + ash).

(4) Vitamin A is expressed in retinol equivalents (RE) as a function of retinol, beta-carotene, and other carotenoids. Similarly, vitamin B3 (niacin) is expressed in niacin equivalents (NE).

(5) The upper level of sodium intake was suggested by the Food and Nutrition Board (FNB) in 1989, but the real sodium intake in China far exceeds this level.

(6) The upper level for zinc intake is 45 mg per day for male and 37 mg per day for female.

(7) The poverty line is set as $2 per capita per day. We use the 2004 purchasing-power parity (PPP, $1=3.43 yuan) to convert it into Chinese Yuan, which results in 2,504 yuan per year.

4 Model Selection

Three issues must be discussed in the empirical analysis of the demand for nutrients: simultaneity, measurement error and heterogeneity.

First, if labor productivity depends on food consumption and nutrient intake, household income cannot be treated as predetermined or exogenous in the nutrient demand analysis. Therefore, instrumental variables should be employed to tackle this simultaneity bias (Leibenstein, 1957; Behrman and Deolalikar, 1987; Bouis and Haddad, 1992; Bouis, 1994; Strauss and Thomas, 1995, 1998; Subramanian and Deaton, 1996; Gibson and Rozelle, 2002; Meng et al., 2009). Following the current literature, this paper uses the characteristics of working people, who earn money for the family, as instrumental variables of income. We have tried different variables and use the F-test and the Sargan test to test the validity of these instruments, the former is used to test the weak instruments and the latter to test the exogeneity of instruments (Staiger and Stock, 1997; Greene, 2002; Wooldridge, 2002).

Second, the measurement errors in income and food consumption could bias the estimation as well, particularly if the measurement error in food consumption is related to the measurement error associated with occupation which further influences income, we could also have an endogenous problem (Bouis and Haddad, 1992). To reduce the measurement errors, we drop all abnormal observations that have an energy (calorie) intake lower than 520 kilocalories (the estimated energy requirement for a female newborn younger than 0.5 years old) and all that are higher than 8,000 kilocalories (more than 3 times of the average calorie intake for Chinese people). Moreover, the observations with an average nutrient intake higher than twice of the upper levels are also dropped. Regarding the excessive intake of sodium in China, we set the rule of selection at 50,000 mg. In addition, the observations with a per capita income lower than 100 yuan (too low to survive even in rural China) are also dropped. Finally, 3,433 out of 3,821 observations are selected for econometric analyses. In order to deal with the possible sample selection bias, we use the Heckman two step model (Heckman, 1979) and control all possible factors that will lead to measurement errors in food consumption and income in the selection model, including all exogenous variables in the nutrient demand model and the excluded exogenous variables that are used as instruments for income, as suggested by Wooldridge (2002).

Third, heterogeneity in household and community must be controlled to eliminate the potential endogeneity resulting from unobservable effects, such as seasonality, as the survey in a community is conducted at the same time. In our study, we use household characteristics (household size, demographic ratio of specific gender-age cohort, average education of people who cooked in this period, and nutrition knowledge) to account for household heterogeneity and a community dummy to control for community endowments and seasonality.

The descriptive analysis of all explainable variables is shown in Table 2.

Table 2 Definitions and Descriptive Analysis of Variables

Variable	Obs.	Mean	Std. Dev.	Min	Max	Definition
income	3,433	5905.73	6098.87	112	64300	Per capita income in 2004
hhsize	3,433	3.30	1.37	1	11	Household size
sg04	3,433	0.01	0.04	0	0.5	Proportion of girl aged 0 to 4
sg59	3,433	0.02	0.07	0	1	Proportion of girl aged 5 to 9
sg1014	3,433	0.02	0.08	0	1	Proportion of girl aged 10 to 14
sb04	3,433	0.01	0.05	0	0.5	Proportion of boy aged 0 to 4
sb59	3,433	0.02	0.07	0	1	Proportion of boy aged 5 to 9
sb1014	3,433	0.02	0.08	0	1	Proportion of boy aged 10 to 14
sadult	3,433	0.60	0.36	0	3	Proportion of adult aged 15 to 60
tnutrition	3,433	0.08	0.27	0	1	Nutrition dummy
avecookedu	3,433	1.54	1.25	0	5	Average education level of people who cooked in the past week
nworker	3,194	1.32	1.01	0	6	Number of working people in the family
workshare	3,194	0.40	0.31	0	1	Proportion of working people in the family
nsecondjob	3,194	0.16	0.44	0	4	Number of people who has a second job in the family
headedu	3,433	7.16	4.30	0	18	Education year of household head
maxworkedu	3,194	1.72	1.49	0	6	Maximum education level of working people

Note: (1) Education level is the highest level of education that people have attained. The level is set from 1 to 6, denoting the levels from primary school, junior middle school degree, senior middle school degree, technical or vocational degree, university or college degree and master's degree or higher, respectively. Education year is the number of years of formal education that people have attended.

(2) Nutrition dummy is set as 1 if any adult in the family has ever heard about the Chinese Pagoda or the Dietary Guidelines for Chinese Residents, otherwise it will be 0.

The empirical practice is conducted following this procedure:

(1) We first use the Heckman two-step procedure to test if the sample used in our study is randomly selected particularly after the dropping of outliers.

(2) To test if the income is endogenous, we use the IV method, try different instrumental variables, and test the validity of the instruments by using the F test and the Sargan test. Finally, we use the characteristics of working people and education as the instruments for income. The results show that the chosen variables are strong instruments (an F value greater than 10) and are not correlated with the error terms (Sargan test not significant), which implies that the instruments are valid. Furthermore, we conduct both OLS and IV regressions,

and use the Hausman test (Hausman, 1978) to compare the results.

(3) On the other hand, if the sample is randomly selected, we use the selected sample directly and run the Hausman test to compare the OLS and IV models.

All of these model comparison tests are shown in Table 3.

Table 3 Model Comparisons

Nutrients	Sample selection	Instrument validity		Model comparison	
		F test	Sargan test	Hausman test	Model chosen
Energy	–1.55	42.79	1.17	210.82***	IV
Protein	–0.76	26.46	1.18	217.77***	IV
Fat	–1.1	42.79	3.98	191.96***	IV
Carbohydrate	1.35	42.79	0.05	264.56***	IV
Fiber	–1.27	42.94	1.83	247.97***	IV
Cholesterol	–0.66	45.08	1.39	172.19***	IV
Vitamin A	–0.9	42.79	2.89	182.42***	IV
Thiamin-B1	–1.62	51.14	4.09	2.56	OLS
Riboflavin-B2	–1.48	26.47	0.72	157.88***	IV
Niacin-B3	–1.34	26.47	1.42	194.95***	IV
Vitamin C	–1.08	42.27	0.16	170.06***	IV
Vitamin E	–1.21	65.34	1.82	177.56***	IV
Calcium	1.97**	51.4	1.22	5.96**	IV-Heckman
Phosphorus	–1.42	26.46	1.64	215.33***	IV
Potassium	–2.00**	51.4	0.06	12.35***	IV-Heckman
Magnesium	–1.55	26.46	1.73	217.19***	IV
Sodium	–0.92	42.79	0.23	156.71***	IV
Iron	–1.49	26.46	0.71	211.58***	IV
Zinc	–1.27	26.47	0.95	217.03***	IV
Selenium	–0.28	42.79	2.79	189.20***	IV
Copper	–1.08	42.79	1.52	182.98***	IV
Manganese	–2.11**	51.4	0.11	5.26**	IV-Heckman

Note: (1) *, ** and *** denote significance levels at 10%, 5% and 1%, respectively.

(2) In the last column, OLS, and IV denote OLS model, and IV model, respectively.

(3) We use the share of working people, number of persons who have a second job and years of education of the household head as instruments for income in the function of energy, fat, carbohydrates, fiber, cholesterol, vitamin A, vitamin C, sodium, selenium, and copper. In the function of thiamin, we use the number of working people to replace the share of working people. For protein, riboflavin, niacin, calcium, phosphorus, potassium, magnesium, iron, zinc, and manganese, we use the number of people who have a second job, and years of education of the household head as instruments for income. In addition, the number of working people and the number of people who have a second job are used as instruments for income for vitamin E.

5 Results and Discussion

5.1 Full Sample

The estimated income elasticities of all nutrients are shown in the first column of Table 4, corresponding to the selected models in Table 3. First of all, we find most elasticities are positive and statistically significant, except for vitamin A, vitamin E, and sodium; this implies that the models fit the data quite well and the intakes of most nutrients indeed increase with income. However, the income elasticities of all nutrients are relatively low, with the highest value being 0.31

Table 4 Income Elasticities of Nutrients

Nutrients	Elasticity		
	Full sample	Below poverty line	Above poverty line
Energy	0.1637***	0.3222***	0.0637
Protein	0.2731***	0.2460**	0.0976
Fat	0.1607***	0.2099	0.0837
Carbohydrate	0.1529***	0.3076**	0.0731
Fiber	0.1803***	0.4406***	0.0566
Cholesterol	0.2614***	0.3089	0.4328**
Vitamin A	0.1482	0.3060	0.1938
Thiamin-B1	0.0251**	0.1183	0.1536
Riboflavin-B2	0.3093***	0.3250**	0.0667
Niacin-B3	0.2976***	0.2248*	0.1487
Vitamin C	0.1252*	0.0864	0.1665
Vitamin E	0.0438	0.2149	0.1205
Calcium	0.2226**	0.2395	–0.0573
Phosphorus	0.2249***	0.2246**	0.1164
Potassium	0.2517***	0.2757**	0.0818
Magnesium	0.2077***	0.4600**	0.0662
Sodium	–0.0081	–0.0602	–0.1069
Iron	0.2493***	0.2410**	0.1658*
Zinc	0.2287***	0.2188**	0.1129
Selenium	0.2116***	0.3062**	0.1550
Copper	0.1491***	0.2454**	0.0079
Manganese	0.1334***	0.2130*	0.0304

Note: (1) *, ** and *** denote significance levels at 10%, 5% and 1%, respectively.

(2) The second and third columns refer to the sample with income below and above the aforementioned poverty line (2,504 yuan per year), respectively.

(vitamin B2). Consistent with our theoretical framework, the income elasticities are generally smaller than that in the study of Huang and Gale (2009).

In particular, the energy intake rises very slowly with income, with a 10% increase in income (the average growth rate of income in China in the past three decades), calorie intake only increases by 1.64%, which is much lower than Ye and Taylor's estimation in 1995 for the low-income and middle-income households (2.1%–4.5%), but higher than that for the highest-income households (0.2%). The results are reasonable since the Chinese people have experienced a remarkable income growth during the period 1995–2004, thus their calorie elasticity with respect to income falls.

Moreover, we also find that the protein elasticity with respect to income is 0.27, substantially higher than the income elasticity of fat and carbohydrates, consistent with previous findings that Chinese people substitute staple food such as cereals that are rich in carbohydrates with animal products which are rich in fat and protein (e.g., Popkin, 1993, 2001; Zhai et al., 2009; Huang and Gale, 2009). Accordingly, the significant positive income elasticity of cholesterol (mainly in animal products) can also be explained by dietary change. The significant income elasticity of fiber and water-soluble vitamins (B1, B2, B3, and C) can be attributed to the rising consumption of fruit, poultry and dairy produce, which are the main sources of fiber and vitamins (Huang and Gale, 2009).

In addition, the intake of most minerals rises slowly with income (with an income elasticity ranging from 0.13 to 0.25). However, the intake of fat-soluble vitamins (A and E) and sodium does not change much as income grows. It is possible that Chinese people already consume too much of them (about two and three times that of the reference intake, respectively), thus their intake is not sensitive to income change.

5.2 Subsample Analysis

The previous section presents the mean elasticity for the population. However, the nutrient response to income of the lower income households can be higher than that of households with higher income levels. Ravallion (1990) and Huang and Gale (2009) have presented empirical evidence asserting that poor households have higher income elasticities of nutrients than rich ones do. Therefore, we separate the families under poverty lines from others and estimate the nutrient elasticities with respect to income for them separately. Their elasticities are presented in the last two columns of Table 4 and the model comparisons are shown in Table 5. Since no obvious sample selection bias is detected in the full sample, we directly use the selected sample.

Table 5 Model Comparisons for Subsamples

Income group	Below poverty line				Above poverty line			
Nutrients	Instrument		Comparison	Model chosen	Instrument		Comparison	Model chosen
	F test	Sargan test	Hausman test		*F* test	Sargan test	Hausman test	
Energy	10.34	0.36	105.39***	IV	17.40	0.65	135.79***	IV
Protein	10.34	1.38	91.95***	IV	17.40	0.61	142.62***	IV
Fat	10.34	0.01	78.00***	IV	17.40	2.03	143.85***	IV
Carbohydrate	10.34	0.88	124.01***	IV	17.40	1.38	149.76***	IV
Fiber	10.34	0.29	92.12***	IV	17.62	0.83	144.00***	IV
Cholesterol	8.95	0.29	70.34***	IV	18.72	3.20	129.24***	IV
Vitamin A	10.34	1.42	80.54***	IV	17.40	1.40	109.08***	IV
Thiamin-B1	10.34	0.84	91.94***	IV	17.40	1.25	165.66***	IV
Riboflavin-B2	10.34	1.33	76.41***	IV	17.40	3.64	110.69***	IV
Niacin-B3	10.34	1.88	79.06***	IV	17.45	0.17	140.56***	IV
Vitamin C	10.22	0.62	70.17***	IV	17.22	0.99	134.19***	IV
Vitamin E	10.34	0.33	65.95***	IV	22.88	1.92	146.00***	IV
Calcium	10.34	1.64	83.15***	IV	17.40	0.18	128.24***	IV
Phosphorus	10.34	0.71	88.18***	IV	17.40	0.11	150.86***	IV
Potassium	9.78	1.96	74.45***	IV	17.40	0.86	135.58***	IV
Magnesium	9.78	0.91	87.43***	IV	17.40	0.14	141.09***	IV
Sodium	10.34	0.58	66.54***	IV	17.40	2.87	67.76***	IV
Iron	10.34	2.23	75.10***	IV	17.40	1.05	170.87***	IV
Zinc	10.34	1.38	92.96***	IV	17.45	1.84	152.42***	IV
Selenium	10.34	0.55	73.21***	IV	17.40	0.33	142.63***	IV
Copper	10.34	0.89	90.78***	IV	17.40	1.11	128.27***	IV
Manganese	10.34	0.43	94.03***	IV	17.40	0.08	152.19***	IV

Note: (1) *, ** and *** denote significance levels at 10%, 5% and 1%, respectively.

(2) OLS, IV denote OLS model and IV model, respectively.

(3) We use the number of working people, number of people who have a second job, and the maximum education level of the working people as instruments for income in the above-poverty-line sample. While in the regression of vitamin E, these instruments are not valid anymore, thus we use the number of working people and the maximum education level of the working people as instruments for income. In the below-poverty-line sample, we use the number of working people and the education of the household head as instruments for income. In addition, we tried different instruments and cannot find one with an F test higher than 10 in the regression of cholesterol, potassium and magnesium, therefore, we use the one with the highest F value, which is the share of working people and the education of the household head.

Consistent with previous studies (e.g., Ravallion, 1990; Huang and Gale, 2009), the estimated elasticities of most nutrients with respect to income are higher in poor families, but their effect is still limited. Particularly, poor households have an income elasticity of energy that is about 0.32, while for the families above the poverty line, income elasticity of energy is less than 0.06 and not significant, implying that income growth has no significant influence on calorie intake for rich people, which is consistent with previous studies that rich people care more about other attributes of the food rather than energy (e.g., Behrman and Deolalikar, 1987; Behrman et al., 1988; Ye and Taylor, 1995; Gao et al., 2013; Jensen and Miller, 2010). Moreover, the elasticities of three energy-yielding nutrients suggest that the role of carbohydrates and protein in calorie intake rises with income for very poor families, implying that families below the poverty line still depend heavily on grains and other plant food, which also explains the high income elasticity of fiber.

In addition, the intake of vitamin B2, B3 and most minerals (except for calcium and sodium) for poor people will also increase significantly along with income growth, which indicates that income growth indeed can relieve poor people from malnutrition, as argued by the World Bank (1981), but the effect is marginal. On the other hand, for the households above the poverty line, income increase will lead to a significant increase in the consumption of cholesterol and iron. As aforementioned, cholesterol and iron mainly come from animal products, which are only widely consumed by rich people.

In general, we can make a conclusion that economic growth indeed results in nutritional improvement in China, but the magnitude is limited and its effects vary for different income groups. For the poorest families, income growth will lead to a higher consumption of plant food, which is rich in carbohydrates and fiber. However, once people are released from poverty, they have a higher demand for animal products that are rich in cholesterol. Therefore, consistent with the suggestion of Bouis and Haddad (1992), we would recommend that public policy aiming at improving the nutritional status of the people should not depend on income growth, and more direct government intervention must be developed to improve nutritional consumption, such as biofortification. According to the study of Qaim et al. (2007), biofortified crops can reduce the problem of micronutrient malnutrition in a cost-effective way.

6 Conclusion

This paper sheds light on the current debate over how the demand for nutrients changes with income and whether malnutrition can be eliminated by economic growth. We discuss the contradictory findings of the impact of income on nutrient intakes briefly and compare the two widely used approaches to estimate nutrient elasticities with respect to income. Particularly, we theoretically compare the direct and indirect approaches to the estimation of nutrition elasticities, and find that the indirect approach often leads to an upward bias. Hence the elasticities in the current literature, which are mainly based on the indirect approach, are regularly overestimated.

Then, we use the CHNS 2004 data to estimate the income elasticities of 22 nutrients in China. Consistent with Behrman and Deolalikar (1987), we find that the income elasticities of most nutrients are quite small, implying that an increase in income will not result in a substantial improvement in nutrient intake. Consistent with the theoretical framework, our estimates are significantly lower than the findings in the current literature using the direct approach (Huang and Gale, 2009).

Moreover, the effect of income growth varies in different income groups. In particular, families under the poverty line have positive elasticities for protein, carbohydrates, fiber, vitamin B2, B3 and most minerals, while those above the poverty line have significant positive elasticities only for cholesterol and iron, resulting from changes in the structure of food consumption from grain to meat. Accordingly, we suggest that more direct government intervention aiming at improving nutrition should be developed separately for people under the poverty line from those out of poverty to improve the nutritional status in China, in order to achieve better health for the Chinese people.

Another issue we must address is that our conclusion mainly rests on the proportional change in income, but not the income change in absolute values. As argued by Bouis and Haddad (1992), very large percentage increases in income for the very poor do very little to change their income status, while relatively small changes in absolute income can have a very large effect. Moreover, the income elasticity of nutrients might not be a linear function of income. Thus, further research should aim to estimate the nutrient elasticities with respect to income for different income groups. In addition, annual data does not reflect seasonal fluctuations in nutrient intake and thus seasonal nutrient surpluses or shortfalls, such as the unusual levels of food consumption measured during several traditional Chinese holidays (Ye and Taylor, 1995). Therefore, further research should focus on these limitations by using more detailed panel data.

References

Behrman J R, Deolalikar A B (1987). Will developing country nutrition improve with income—a case study for rural south India. The Journal of Political Economy, 95(3): 492–507

Behrman J R, Deolalikar A B, Wolfe B L (1988). Nutrients: Impacts and determinants. The World Bank Economic Review, 2(3): 299–320

Bouis E H (1994). The effect of income on demand for food in poor countries: Are our food consumption databases giving us reliable estimates? Journal of Development Economics, 44: 199–226

Bouis E H, Haddad L J (1992). Are estimates of calorie-income elasticities too high?—a

recalibration of the plausible range. Journal of Development Economics, 39: 333–364
Deaton A (1988). Quality, quantity and spatial variation of price. American Economic Review, 78(3): 418–430
Deaton A (1997). Nutrition, children, and intra-household allocation. In: Deaton A. (Eds.), The Analysis of Household Survey, Chapter 4, 170–221, Baltimore and London: The Johns Hopkins University Press
Drewnowski A, Popkin B M (1997). The nutrition transition: New trends in the global diet. Nutrition Reviews, 55(2): 31–43
Du S, Lu B, Zhai F, Popkin B M (2002). A new stage of the nutrition transition in China. Public Health Nutrition, 5(1A): 169–174
Du S, Mroz T A, Zhai F, Popkin B M (2004). Rapid income growth adversely affects diet quality in China-particularly for the poor. Social Science & Medicine, 59: 1505–1515
Gale F, Huang K (2007). Demand for food quantity and quality in China. Washington DC: U.S. Department of Agriculture, Economic Research Report No. 32, January
Gao Z, Lee J, Yu X (2013). Consumer demand for diet quality: Evidence from the Healthy Eating Index. Forthcoming in Australian Journal of Agricultural and Resource Economics
Drewnowski A, Popkin B M (1997). The nutrition transition: New trends in the global diet. Nutrition Reviews, 55(2): 31–43
Gibson J, Rozelle S (2002). How elastic is calorie demand? Parametric, nonparametric and semiparametric results for urban Papua New Guinea. The Journal of Development Studies, 38(6): 23–46
Greene W H (2002). Econometric Analysis (5th edition). New Jersey, USA: Prentice Hall
Guo X, Mroz T A, Popkin B M, Zhai F (2000). Structural change in the impact of income on food consumption in China: 1989–1993. Economic Development and Cultural Change, 48(4): 737–760
Hausman J A (1978). Specification tests in econometrics. Econometrica, 46(6): 1251–1271
Heckman J J (1979). Sample selection bias as a specification error. Econometrica, 47(1): 153–161
Huang K S (1996). Nutrient elasticities in a complete food demand system. American Journal of Agricultural Economics, 78: 21–29
Huang K S (1999). Effects of food prices and consumer income on nutrient availability. Applied Economics, 31: 367–380
Huang K S, Gale F (2009). Food demand in China: Income, quality, and nutrient Effects. China Agricultural Economic Review, 1(4): 395–409
Institute of Nutrition and Food Safety, and Chinese center for Disease Control and Prevention (CDC, 中国疾病预防控制中心营养与食品安全所) (2002). China Food Composition 2002 (中国食物成分表 2002). Beijing, China: Peking University Medical Press (北京大学医学出版社)
Institute of Nutrition and Food Safety, and Chinese center for Disease Control and Prevention (CDC, 中国疾病预防控制中心营养与食品安全所) (2004). China Food Composition 2004 (中国食物成分表 2004). Beijing, China: Peking University Medical Press (北京大学医学出版社)
Jensen R T, Miller N H (2010). A revealed preference approach to measuring hunger and under-nutrition. Working Paper, NBER
Lancaster K J (1966). A new approach to consumer theory. The Journal of Political Economy, 74(2): 132–157
Leibenstein H (1957). Economic Backwardness and Economic Growth: Studies in the Theory of Economic Development. New York: Wiley & Sons

Mangyo E (2008). Who benefits more from higher household consumption? The intra-household allocation of nutrients in China. Journal of Development Economics, 86 (2): 296–312

Meng X, Gong X, Wang Y (2009). Impact of income growth and economic reform on nutrition availability in urban China: 1986–2000. Economic Development and Cultural Change, 57(2): 261–295

Pitt M M, Rosenzweig M R (1985). Health and nutrient consumption across and within farm households. Review of Economics and Statistics, 67(2): 212–223

Popkin B M (1993). Nutritional patterns and transitions. Population and Development Review, 19(1): 138–157

Popkin B M (2001). The nutrition transition and obesity in the developing world. The Journal of Nutrition, 131(3): 8715–8735

Qaim M, Stein A J, Meenakshi J V (2007). Eonomics of biofortification. Agricultural Economics, 37(S1): 119–133

Ravallion M (1990). Income effects on undernutrition. Economic Development and Cultural Change, 38(3): 489–515

Shimokawa S (2010). Asymmetric intra-household allocation of calories in China. American Journal of Agricultural Economics, 92 (3): 873–888

Skoufias E, Maro V D, Gonzalea-Cossio T, Ramirez S R (2009). Nutrient consumption and household income in rural Mexico. Agricultural Economics, 40: 657–675

Staiger D, Stock J H (1997). Instrumental variables regression with weak instruments. Econometrica, 65(3): 557–586

Strauss J, Thomas D (1995). Human resources: empirical modeling of household and family decisions. In: Behrman J. R. and Srinivasan T. N. (Eds.), Handbook of Development Economics, Volume 3. Holland, Amsterdam: North-Holland

Strauss J, Thomas D (1998). Health, nutrition, and economic development. Journal of Economic Literature, 36(2): 766–817

Subramanian S, Deaton A (1996). The demand for food and calories. The Journal of Political Economy, 104(1): 133–162

Wang Y, Bentley M E, Zhai F, Popkin B M (2002). Tracking of dietary intake patterns of Chinese from childhood to adolescence over a six-year follow-up period. The Journal of Nutrition, 132(3): 430–438

Whitney E, Rolfes S R (2005). Understanding Nutrition (10th edition). Belmont, CA: Thomson Wadsworth

Wooldridge J M (2002). Econometric Analysis of Cross Section and Panel Data. Cambridge, Massachusetts, and London, England: The MIT Press

World Bank (1981). World development report. Washington: World Bank

Ye X, Taylor J E (1995). The impact of income growth on farm household nutrient intake: A case study of a prosperous rural area in northern China. Economic Development and Cultural Change, 43(4): 805–819

Yu X, Abler D (2009). The demand for food quality in rural China. American Journal of Agricultural Economics, 91(1): 57–69

Zhai F, Wang H, Du S, He Y, Wang Z, Ge K, Popkin B M (2009). Prospective study on nutrition transition in China. Nutrition Reviews, 67(S1): 56–61

Appendix

Explanations to Nutrient Conversion from Food Consumption

1. There are two sets of food consumption data: household food inventory change data and 24-hour individual dietary intake data. The former is used in our analysis for the following reasons. First, edible oil and condiments (salt, sugar, sauces, etc.), which also provide a lot of nutrients, and are very important in Chinese cuisine, are only reported in household food consumption. Second, waste (e.g., spoiled rice, discarded cooked meals fed to pets or animals) is deducted from the change of food inventories to avoid the potential bias as rich families usually produce more waste, as is argued by Bouis and Haddad (1992), Bouis (1994) and Strauss and Thomas (1995, 1998). Food waste generated from eating away from home, which is usually more common and severe, is not reported in the individual dietary intake data. Third, food fed to workers and guests at home is not reported in the survey, the real consumption of food could be lower than the reported change in food inventory for these households, and the nutrient intake would cause an upward bias in this case (Bouis and Haddad, 1992). However, this food leakage is presumably not an important phenomenon, since most families in China serve their guests and workers in a restaurant, not at home. In addition, 24-hour recall data may suffer more from random measurement error because of day-to-day dietary variation, which is reduced in food consumption data by averaging the change in food inventory over three days (Strauss and Thomas, 1998). Thus, the change of the food inventory in our study is more reliable than the individual dietary recall data suggested by Bouis and Haddad (1992).

2. Food consumption is calculated as follows: We first calculate the changes in food inventory during the survey period. Then, as the number of meals eaten at home for the same three consecutive days is also collected for all family members, we can assign different weights to the three daily meals (breakfast, lunch and dinner) according to each person's dietary habit, and multiply these weights by the number of meals eaten at home during this period to calculate the total number of person-days, which is used to divide the inventory change during these days for each food group and generate the food consumption per person per day (Guo et al., 2000; Du et al., 2002; Popkin et al., 2002; Wang et al., 2002; Du et al., 2004).

3. Three potential biases regarding the food consumption data must be mentioned. First, the food eaten away from home is usually higher in fat and energy compared with the foods consumed at home, so that the calorie intake will cause

a downward bias if any family member eats away from home during the three consecutive days (Bouis 1994; Strauss & Thomas 1995; Subramanian & Deaton 1996). Second, since the data is collected in a very short period, while the consumption in different seasons varies remarkably in China, the food consumption data might suffer from seasonal bias. Furthermore, food consumed in weekdays and weekends might differ, thus the weekend effect may also cause a bias in the estimation. However, since all respondents in one community are investigated at the same time, and the community dummies have been controlled in the regression, the last two biases can be controlled.

4. To calculate the nutrient intake, the China Food Composition Tables from 2002 and 2004 (CDC, 2002, 2004) are used to convert the detailed food consumption data to the intake of 22 nutrients as listed in the book. Moreover, the edible proportion of each food item is also used in the conversion to make sure that the nutrient intake is the actual level of nutrition consumed by people, not the nutrient availability (ignoring the heterogeneity of absorption across individuals). We further sum up the nutrient intake from all food products consumed in each household and capture the nutrient intake per capita per day.

5. The income variable used in this paper is the generated per capita income in the survey, both market and nonmarket activities were accounted for (Du et al., 2004). We did not use the total expenditure, as suggested by Bouis and Haddad (1992), because the total expenditure data is not available in this survey.