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Estimation of a censored food demand system and nutrient elasticities: a cross-sectional analysis of Sri Lanka

RESEARCH ARTICLE

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Abstract

A nutritional transition is occurring in Sri Lanka, which steers people away from nutrient-rich diets, contributing to diet-related disease and poor economic performance. This study examines demographic impacts on consumption of major food commodities and estimates price and expenditure elasticities for major food groups and nutrients. Data from the Sri Lankan Department of Census and Statistics Household Income and Expenditure survey are used to estimate price and expenditure elasticities for food commodities and nutrients using the Quadratic Almost Ideal Demand System (QUAIDS). The zero-expenditure problem is circumvented by employing a Tobit model. Results demonstrate the impact of price and income changes on dietary intake of households, and income and nutrition policy recommendations are presented.

Keywords: food demand; nutrient demand; QUAIDS; Tobit
JEL code: C13, D12, R20, R28

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1. Introduction

Nutritional transitions are currently occurring in both developed and developing countries as a result of shifts in dietary consumption and energy expenditure (Meng *et al.*, 2014). These shifts in diet are due to economic, demographic, and epidemiological changes. These changes steer people from nutritionally rich diets to unhealthy diets. Unhealthy diets are often comprised of processed and/or fast foods which provide more calories from fat, saturated fat, trans fat, sodium and added sugars. Such diets are often less nutritious.

Sri Lanka is a developing country which falls into the lower-middle income category. On average, more than 50% of Sri Lankan household income goes toward food (Rathnayaka *et al.*, 2019), and not all consumers have access to sufficient supplies of nutritious food. Rising prices, income inequality, urbanisation, and changes in lifestyle patterns can be detrimental to engaging in healthy lifestyles. Unhealthy dietary habits lead many Sri Lankans toward failure of achieving recommended nutrient intake (Jayawardena *et al.,* 2012, 2013), and may result in under-nutrition, over-nutrition, and obesity. These conditions have led to an increase in diet-related chronic diseases over the last two decades (Jayawardena *et al.*, 2014).

Lack of appropriate nutrition and resultant diet-related disease has resulted in a loss of productive population in Sri Lanka. This loss of productive capacity often results in poor economic performance throughout the country. A potential solution is to implement food policy interventions aimed at nutritional improvement of Sri Lankans. Because Sri Lanka is a multi-cultural country with several religions and ethnic groups, knowledge of food and nutrient demand and consumption is crucial to introducing effective interventions. Comprehensive analysis of food and nutrient consumption with respect to food prices and household socio-economic characteristics is necessary for improved policy implementations (Abdulai and Aubert, 2004; Ecker and Qaim, 2011). Demand analysis for food and nutrients play a crucial role, particularly in relation to calculation of nutrient elasticities. Price and income elasticities can be calculated in order to measure the percentage change in nutrient intake in response to a 1% change in prices and income (Ecker and Qaim, 2011).

High food prices prompt consumers to seek lower-cost alternatives and lower income populations tend to be more sensitive to food prices (Fang *et al*., 2018). Additionally, food demand patterns and nutrient intake are strongly correlated as any change in food prices and/or income impacts food consumption, thus affecting individuals' nutrient availability (Hahn and Davis, 2014; Lin *et al.*, 2014). While price and income elasticities of food represent the principal components in food consumption studies, nutrient elasticities are important as they indicate the impact of changes in food prices and real income on the consumption of nutrients. Given the above, it is imperative to assess food and nutrient consumption at the individual or household level, which provides important insights for broader food and nutritional policies.

Although numerous food demand studies have been conducted for other countries, a review of the literature indicates that there are few national-level studies assessing food, and in particular, nutrient consumption in Sri Lanka. Sahn (1988) studied food consumption in Sri Lanka in order to assess food policy impacts. Nirmali and Edirisinghe (2015) estimated price and income elasticities with respect to the calorie availability of households in the Western province of Sri Lanka. The impacts of climate change on food accessibility in Sri Lanka was recently investigated by Esham *et al.* (2018). Rathnayaka *et al*. (2019) calculated price and income elasticities for a variety of goods and services, including food, under consideration of multiple policy scenarios. However, studies focusing specifically on food and nutrient elasticities are lacking.

The studies of both Sahn (1988), and Nirmali and Edirisinghe (2015) are based on micro data in which zero consumption during the recall period can be commonly observed. To circumvent the infrequent consumption observed in some households, the two-step procedure developed by Heien and Wessells (1990) has been widely utilised in demand studies, whereas Shonkwiler and Yen (1999) proclaim the inconsistency of Heien and Wessells' procedure.

The Almost Ideal Demand System (AIDS) proposed by Deaton and Muellbauer (1980) is a popular framework for studying demand systems in terms of price and income elasticities. Because nonlinearity in the AIDS causes empirical difficulties, the linear approximate AIDS (LA/AIDS) has been extensively used by many researchers in demand studies. Bett *et al.* (2012) examined the demand for meat in rural and urban areas of Kenya using the LA/AIDS, while incorporating socioeconomic and demographic factors in the system. Taljaard (2004) also employed the LA/AIDS to estimate the demand for meat in South Africa. Furthermore, Bilgic and Yen (2013), Nirmali and Edirisinghe (2015), and Ulubasoglu *et al.* (2016) utilised the LA/AIDS to estimate demand elasticities for various food commodities in Turkey, Sri Lanka, and Australia, respectively.

However, after Banks *et al.* (1997) pointed out the inadequate representation of the LA/AIDS when budget shares are not linear in expenditure, the Quadratic Almost Ideal Demand System (QUAIDS) proposed by Banks *et al.* (1997) has garnered wide popularity in demand studies. Addressing malnutrition and undernutrition issues, Abdulai and Aubert (2004) and Ecker and Qaim (2011) employed the QUAIDS to analyze the food and nutrient consumption in Tanzania and Malawi, respectively.

No study examining demand for food and nutrients in Sri Lanka has considered the non-linearity of budget shares in expenditure and the two-step estimation procedure proposed by Shonkwiler and Yen (1999) to avoid the zero-expenditure problem. Thus, we first examine the consumption of food in Sri Lanka, adopting a censored non-linear demand system using Shonkwiler and Yen's (1999) procedure. Second, this study assesses the consumption of nutrients. Hence, this analysis aims to: (1) estimate price and expenditure elasticities of major food commodities; (2) compute nutrient elasticities with respect to food prices and expenditure; and (3) capture demographic impacts on the consumption of major food commodities in Sri Lanka.

2. Methods

Data for this study are obtained from the Household Income and Expenditure Survey (HIES) 2012/13, conducted by the Department of Census and Statistics (DCS) in Sri Lanka in two different time periods (2006-2007 and 2009-2010). The HIES 2012/13 covers all 25 districts in the country and provides information on household income, consumption, demographic and other socio-economic variables for a large sample of 20,536 housing units throughout the country. Weekly consumption of food data was collected for over 200 most-consumed food items in Sri Lanka under 19 subgroups, such as cereals, processed food, vegetables, fish, meat, and dairy products (Mayadunne and Romeshun, 2013).

The approach utilised in this study is centered on the consumer expenditure allocation, which is assumed to follow the two-stage budgeting procedure. In the first stage, the consumer primarily allocates total expenditure among various commodity groups such as food, clothing, housing, transport, and entertainment. Further, it is assumed that food groups are weakly separable from all other commodities demanded by the consumer. Therefore, only the expenditures allocated in the second stage among twelve food groups (cereals, food away from home (FAFH), pulses, vegetables, leafy vegetables, yams, meat, fish, dried fish, coconut, dairy products, and fruits) are considered for this study.

Household food consumption is analyzed using the QUAIDS proposed by Banks *et al.* (1997):

$$W_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln P_j + \beta_i \ln\left(\frac{m}{a(P)}\right) + \frac{\lambda_i}{b(P)}\left\{\ln\left[\frac{m}{a(P)}\right]\right\}^2 \quad (1)$$

where W_i is budget share of i^{th} food group, P_j is prices of the j^{th} food groups, m is the total expenditure on all food items per household, $a(P)$ and $b(P)$ is functions of the vector of prices P. α_i, γ_{ij},β_i, and λ_i are the parameters to be estimated.

The HIES does not provide actual market prices of commodities. Following the common practice undertaken in the literature (Park *et al.*, 1996; Weliwita *et al.*, 2003), a proxy of unit values is used as prices for each food item (P_{ki}). These measures are obtained by dividing expenditure by quantity. Nevertheless, each food group consists of more than one food item. Hence, based on the prices calculated for each food item, prices for each food group (P^*) are computed as the Stone's Price Index:

$$\ln(P^*) = \sum_{k=1}^{m} W_{ki} \ln(P_{ki}) \tag{2}$$

Where W_{ki} and P_{ki} represent the budget share and price of k^{th} food item in the i^{th} food group, respectively. W_{ki} is a budget share that is taken as a weight; thus, food items with higher budget shares contribute more to the price index than do food items with a lower budget share.

Further, some households may report zero expenditure on certain food commodities due to non-preference, responses to market price, or due to sufficient household inventory during the survey period (Cheng and Capps, 1988). Accordingly, for those households that reflect zero-expenditure, P^* is replaced by the average values of the non-zero P^*s within the ideal cluster (Weliwita *et al.*, 2003).

We employ the two-step procedure developed by Shonkwiler and Yen (1999) to circumvent the infrequent consumption observed in some households. A probit model is utilised in the first step to model the market participation of households.

Sample statistics with respect to budget shares, price indices, and expenditure are presented in Table 1. The cereals group has the highest budget share amongst all food groups. Moreover, cereals, vegetables, pulses, and coconut report the least values for the proportions of zero consumption, indicating that these are the food groups that are most consumed by Sri Lankans.

After obtaining probit estimates ($\hat{\tau}_i$) in the first step, the normal probability density ($\phi(Z'_{ih}\hat{\tau}_i)$) and the cumulative distribution ($\Phi(Z'_{ih}\hat{\tau}_i)$) are calculated for each household. Subsequently, ($\phi(Z'_{ih}\hat{\tau}_i)$) and ($\Phi(Z'_{ih}\hat{\tau}_i)$) are incorporated into the QUAIDS specified in Equation 2 in the second step; therefore, the estimating model is:

$$W_i^* = \Phi(Z'_{ih}\hat{\tau}_i)\left(\alpha_i + \sum_j \gamma_{ij} \ln(P_j^*) + \beta_i \ln\left(\frac{m}{a(P^*)}\right) + \frac{\lambda_i}{b(P^*)}\left\{\ln\left[\frac{m}{a(P^*)}\right]\right\}^2\right) + \delta_i \phi(Z'_{ih}\hat{\tau}_i) + \varepsilon_i \tag{3}$$

Table 1. Sample statistics of budget shares, prices and expenditure of food items in Sri Lanka.[1]

	Budget shares W_i			**Price indexes P^***	
	Mean	**Std. Dev.**	**Proportion of zero consumption (%)**	**Mean**	**Std. Dev.**
Cereals	0.24	0.12	2.37	4.28	0.29
FAFH[2]	0.13	0.18	24.52	0.64	2.03
Pulses	0.05	0.04	9.30	5.25	0.27
Vegetables	0.09	0.05	3.93	4.67	0.29
Leafy vegetables	0.02	0.02	21.83	2.51	1.10
Yams	0.03	0.02	17.00	-1.98	1.12
Meat	0.05	0.07	61.40	6.03	0.16
Fish	0.12	0.10	23.87	5.96	0.39
Dried fish	0.05	0.06	25.26	6.28	0.32
Coconut	0.09	0.06	5.98	3.52	0.31
Dairy products	0.10	0.09	26.23	6.67	0.43
Fruits	0.03	0.04	38.31	2.23	0.86
Total food expenditure (LKR)	2,748.30	1,342.89			

[1] LKR = Sri Lankan Rupee; 1 USD = 159.09 LKR

[2] FAFH: food away from home.

To capture how purchasing decisions for each and every food group vary based on demographic characteristics, demographic variables (Table 2) are incorporated into the first step probit model. Sri Lanka has several ethnic groups: Sinhalese, Tamils, Moors, Malays, Burghers, and other. Regions can be classified under three different categories: urban, estate, and rural.[1] Thus, ethnicity and region are considered in the form of dummy variables. When household size is of significance, it is more realistic to take household size as proportional to the gender and age of household members. Compared to a household with children, a household of the same size with adults may consume more food and nutrients. Hence, by utilising the information provided in Nanayakkara (1994), an adult equivalent is constructed for each household based on the gender and age composition of its residents, thereby yielding a more accurate estimate for food and nutrient consumption than if household size was used.

The interpretations of demographic variables considered in the probit model are based on the marginal effects that are corrected for heteroscedasticity issues in the model (Greene, 2011). Furthermore, cross-sectional survey data and the incorporation of $\phi(Z_{ih}^{'}\hat{\tau}_i)$ and $\Phi(Z_{ih}^{'}\hat{\tau}_i)$ introduce heteroscedasticity to the QUAIDS (Shonkwiler and Yen, 1999). The Generalized Method of Moments (GMM) is employed to avoid possible heteroscedasticity and endogeneity of budget share equations (Abdulai and Aubert, 2004). However, as in conventional systems, the adding-up restriction does not hold in censored demand systems. Consequently, the QUAIDS is estimated by considering all equations (Ecker and Qaim, 2011; Yen *et al.*, 2002).

Next, expenditure elasticity and uncompensated price elasticities are calculated according to Equations 4 and 5 (Ecker and Qaim, 2011).

$$\eta_m = \left(\frac{\mu_i}{W_i^*}\right) + 1 \tag{4}$$

where $\mu_i = \frac{\partial W_i^*}{\partial \ln m} = \Phi\left(Z_{ih}^{'}\hat{\tau}_i\right)\left(\beta_i + \frac{2\lambda_i}{b(P^*)}\left\{\ln\left[\frac{m}{a(P^*)}\right]\right\}\right)$.

$$\eta_p = \left(\frac{\mu_{ij}}{W_i^*}\right) - \delta_{ij};\ \delta_{ij} = 1 \text{ for } i = j,\ \delta_{ij} = 0 \text{ for } i \neq j \tag{5}$$

where $\mu_{ij} = \frac{\partial W_i^*}{\partial \ln P_j^*} = \Phi\left(Z_{ih}^{'}\hat{\tau}_i\right)\left(\gamma_{ij} - \mu_i\left(\alpha_j + \sum_k \gamma_{jk} \ln P_k^*\right) - \frac{\beta_j\lambda_i}{b(P^*)}\left\{\ln\left[\frac{m}{a(P^*)}\right]\right\}^2\right)$.

Similar to demand for food commodities, nutrient demand can be created as consumers maximise utility from various attributes of the food such as nutrient content, taste, texture, and color. According to Lancaster (1966), consumers maximise their utility not from the good per se, but from the characteristics it possesses. The consumption of nutrients depends on food prices, income, and demographic variables. As evidenced by past studies (Abdulai and Aubert, 2004; Behrman and Wolfe, 1984; Variyam *et al.*, 2002; Weinberger,

[1] Urban region covers all residential areas governed by a municipal council or an urban council. Plantation areas that are more than 20 acres and have no less than ten residential laborers come under the estate region. Areas that cannot be grouped under urban or estate regions are considered rural region.

Table 2. Sample statistics of demographic variables.

	Variables	Mean	Std. Dev.
Region	Urban	0.252	-
	Estate	0.090	-
	Rural (reference category)	0.658	
Ethnicity	Sinhalese	0.678	-
	Tamils	0.226	-
	Other ethnicities (reference category)	0.097	
Adult equivalent		3.039	1.351

2001), the total nutrient demand is a function of household budget constraints, such as income and prices of food commodities, as well as demographic indicators.

To facilitate direct estimation of elasticities, Abdulai and Aubert (2004), Behrman and Wolfe (1984), and Tian and Yu (2013) suggest transforming nutrient intake and other explanatory variables into log values. Hence, demand for nutrients is estimated according to the following model:

$$\ln N_{hp} = \alpha + \beta \ln P_i^* + \gamma \ln m_h + \delta Z_h + \mu_h \quad (6)$$

Where N_{hp} is p^{th} nutrient intake in the h^{th} household, P^* is a vector of price indices of food groups, m_h is total food expenditure in the h^{th} household, and Z_h *is* a vector of demographic variables.

Since the HIES does not provide data on nutrient intake of households, dietary intake of calories, proteins, fats, and carbohydrates can be derived from the food consumption data provided by the HIES. Consequently, nutrient intakes are calculated using nutrient databases available in the Biodiversity for Food and Nutrition (2016), Sri Lanka and the US Department of Agriculture (2016). Following Nanayakkara (1994), intake of nutrients is estimated as:

$$N_{ihp} = \sum_{k=1}^{m} \left[Q_k . g_k \left(\frac{P_k}{100} \right) f_{N_{kp}} \right] \quad (7)$$

Where N_{ihp} is h^{th} household's total intake of the p^{th} nutrient gained through the consumption of the i^{th} food group, Q_k is consumption of the k^{th} food item per week, g_k is gram equivalent of the k^{th} food item, P_k is percentage of edible portion of the k^{th} food item, and f_{Nkp} is conversion factor for the respective nutrient. Thus:

$$N_{hp} = \sum_{i=1}^{n} N_{ihp} \quad (8)$$

The vector Z_h in Equation 6 contains the same demographic variables which are considered for food consumption (Table 2), where Z_{hd} represents dummy variables (sector and ethnicity). Therefore, interpretations of nutrient intake with respect to sector and ethnicity are based on the percentage effects calculated as (Greene, 2012):

$$\%\left(\Delta E\left[N_{hp}|Z_{hd}\right]/\Delta Z_{hd}\right) = 100\% \left\{ \frac{E\left[N_{hp}|Z_{hd}=1\right] - E\left[N_{hp}|Z_{hd}=0\right]}{E\left[N_{hp}|Z_{hd}=0\right]} \right\} = 100\%\left[exp\left(\delta_{Z_{hd}}\right) - 1\right] \quad (9)$$

Further, nutrient consumption may vary with households' purchasing power. Thus, nutrient elasticities are computed for the population, poorest, and richest quintiles with respect to food prices and expenditure. The estimation of demand for calories, proteins, fats, and carbohydrates is carried out as a system of equations using the Iterated Seemingly Unrelated Regression (ITSUR).

Endogeneity between nutrient intake and total expenditure has received some concern in nutrient demand models. According to the 'efficiency-wage hypothesis', workers adjust food and nutrient consumption based on wages they earn; hence, total food expenditure can be endogenous with nutrient intake (Abdulai and Aubert, 2004; Ecker and Qaim, 2011). This hypothesis is applicable for the workers whose livelihoods depend on wages. In this study, household income is based not only on income of household members, but also on other secondary sources, such as income from rented properties, elderly payments, monthly allowances from poverty alleviation programs, etc. In this study, given that the proportion of workers who earn wages is less than 40%, endogeneity bias is disregarded. Nevertheless, the presence of heteroscedasticity in the model is confirmed by White's heteroscedasticity test; thus, standard errors are obtained through a heteroscedasticity-consistent covariance matrix.

3. Results and discussion

3.1 Demographic, price, and expenditure effects on food consumption

Demographic determinants of the market participation of households for each food group are interpreted based on the significant marginal effects of probit estimates. Therefore, only the marginal effects of the 1st stage probit estimates are shown in Table 3.

Household demographics are found to substantially influence consumer purchases; thus, food retail outlet managers should understand the demands of their customer base. Urban households, compared to rural households, show less tendency to consume cereals, pulses, vegetables, yams, dried fish, and coconut, while moving toward FAFH, leafy vegetables, meat, fish, dairy products, and fruits. Marginal effects with respect to the estate sector reveal that estate households are more likely to consume pulses, dried fish, and dairy products than rural households. This is likely due to the estate region covering hill country in Sri Lanka, and being located away from coastal areas. Consequently, estate communities face higher prices for certain products, such as fish, due to shortages and higher transportation costs. Additionally, amongst all regions, the estate region reports the lowest household and per capita incomes as well as the highest average household size. Given this, lower priced dried fish is demanded by these households as a more reasonable way to obtain necessary animal proteins. Amidst the food groups that are less likely to be consumed by households in estate areas, consumption of fish is the lowest.

Of the two major ethnicities, both Sinhalese and Tamil households express similar behavior for most of the food groups. These two ethnicities demand pulses, vegetables, and yams more than other ethnicities. However, they are less likely to consume FAFH, meat, and fish. The majority of Sinhalese and Tamils are Buddhists and Hindus in religion, respectively. Hence, the reported low tendencies to purchase animal source foods of Sinhalese and Tamil households may be affected by religious impacts because most Buddhists and Hindus are vegetarians.

The marginal effects of adult equivalents report significant values for all food groups. Households with many members, or more adults compared to children, might result in higher adult equivalents. As expected, with an increase in household size or adult equivalent, households are more likely to buy all food commodities, except FAFH. It would likely not be economical for large households to purchase FAFH in bulk quantities.

Table 3. Marginal effects of first-step probit estimates.[1]

Food group	Region		Ethnicity		Adult equivalent
	Urban	Estate	Sinhalese	Tamils	
Cereals	-0.009**	-0.010	-0.006	0.004	0.037**
FAFH[2]	0.149**	-0.116**	-0.158**	-0.140**	-0.008**
Pulses	-0.015**	0.046**	0.205**	0.080**	0.049**
Vegetables	-0.011**	-0.004	0.010*	0.010*	0.047**
Leafy vegetables	0.030**	-0.075**	0.188**	0.030	0.045**
Yams	-0.038**	-0.016	0.131**	0.105**	0.053**
Meat	0.116**	-0.044**	-0.367**	-0.049*	0.052**
Fish	0.073**	-0.299**	-0.107**	-0.031**	0.064**
Dried fish	-0.021**	0.094**	0.147**	-0.592**	0.033**
Coconut	-0.015**	-0.006	-0.007	-0.003	0.037**
Dairy products	0.165**	0.049**	-0.001	-0.024*	0.054**
Fruits	0.070**	-0.127**	0.023*	-0.075**	0.026**

[1] Significance levels at 1%** and 5%*.

[2] FAFH: food away from home.

Table 4 presents uncompensated own-price and cross-price elasticities for the 12 food groups. Own-price elasticities of all food groups are statistically significant at the 1% level, and negative as expected, which is consistent with demand theory. Meat is found to be price-elastic, while all other food groups are price-inelastic. Price elasticities of the most popular food groups among Sri Lankans such as cereals, pulses, vegetables, and coconut lie within -0.6 and -0.7. Nonetheless, price elasticities of FAFH, leafy vegetables, yams, fish, dairy products, and fruits vary between -0.8 and -1.0, and are therefore on the verge of being price elastic.

Members of the food industry can note these findings and adjust marketing and pricing strategies as appropriate. Cereals, pulses, vegetables, and coconut are foods highly demanded by Sri Lankans regardless of market prices. When market prices rise, Sri Lankans are more likely to reduce consumption of meat, FAFH, leafy vegetables, yams, fish, dairy products, and fruits. The main meal of Sri Lankans is rice with several side dishes of pulses, mostly red lentils, and vegetables. A curry of animal proteins (meat, fish, or eggs) may be added for non-vegetarian meals, and coconut serves as one of the essential ingredients in making these curries. Given that all sources of animal proteins are price elastic, consumers may approach dried fish as a substitute for costly animal food sources in order to obtain animal proteins.

Cross-price elasticities highlight the substitutability of cereals with FAFH and yams. This information is useful for retail managers when determining store stocks. Because the main meals in Sri Lanka are often accompanied by curries that include vegetables and animal source foods, it is not surprising to observe the complementary behavior of cereals with vegetables, fish, and dried fish. Further, complementarity between vegetables and coconut indicates usual cooking patterns of Sri Lankan meals because almost all vegetables are cooked using coconut milk. With respect to the substitutability of animal source foods, it should be noted that meat can be substituted by either fish or dried fish.

Sri Lankans normally consume fruits as dessert, and dairy products for morning and evening tea. Therefore, neither fruits nor dairy products are accompanied by other food groups. Further, none of the other food

Table 4. Price and expenditure elasticities of food groups.[1,2]

Price elasticity	**Cereals**	**FAFH[3]**	**Pulses**	**Vegetables**	**Leafy vegetables**	**Yams**	**Meat**	**Fish**	**Dried fish**	**Coconut**	**Dairy products**	**Fruits**
Cereals	-0.67**	0.02**	0.01**	-0.08**	0.00	0.01**	0.11*	-0.07**	-0.09**	0.02**	-0.01	-0.04**
FAFH[3]	0.10**	-0.87**	0.03**	0.05**	0.01**	0.00**	0.00	-0.02**	0.02**	0.05**	-0.02**	-0.03**
Pulses	-0.09**	-0.05**	-0.67**	-0.09**	-0.02**	0.00	-0.20**	0.06**	-0.07**	-0.04**	-0.07**	0.00
Vegetables	-0.15**	0.07**	-0.01	-0.71**	0.00	0.01*	0.20**	0.03**	-0.05**	-0.03**	0.05**	-0.06**
Leafy vegetables	0.14**	0.09**	0.04**	0.05**	-0.95**	0.02**	0.03*	0.09**	-0.03**	0.19**	0.01	-0.03**
Yams	0.03	-0.03**	-0.01	-0.02	0.00	-0.88**	0.02	-0.07**	0.04**	-0.09**	-0.06**	0.00
Meat	0.24**	-0.02	-0.18**	0.20**	0.01	0.00	-1.34**	0.13**	0.02*	-0.09**	-0.08**	0.03**
Fish	-0.17**	-0.04**	0.00	0.00	0.02**	-0.02**	0.07**	-0.98**	-0.01	-0.10**	0.07**	0.03**
Dried fish	-0.14**	0.08**	-0.01	-0.02*	0.00	0.02**	0.02*	-0.02*	-0.51**	0.03**	0.05**	-0.04**
Coconut	0.02**	-0.01**	-0.04**	-0.06**	0.02**	-0.02**	-0.04**	-0.07**	-0.03**	-0.66**	0.00**	-0.01**
Dairy products	-0.19**	-0.15**	-0.11**	-0.03**	-0.02**	-0.03**	-0.05**	0.14**	0.02**	-0.16**	-0.98**	0.03**
Fruits	-0.22**	-0.07**	-0.06**	-0.10**	-0.01	-0.02**	0.03**	0.05**	-0.02**	-0.10**	-0.03**	-0.83**
Expenditure elasticity	0.76**	0.92**	0.70**	0.60**	0.24**	1.09**	1.19**	1.28**	0.52**	0.79**	1.69**	1.53**

[1] Significance levels at 1%** and 5%*.

[2] Diagonal price elasticities are own-price elasticities. Off diagonal elasticities are cross-price elasticities.

[3] FAFH: food away from home.

groups can serve as substitutes for fruits and dairy products. Given this, it is not realistic to discuss cross-price elasticities of fruits and dairy products with other food groups.

All food groups report statistically significant expenditure elasticities at the 1% level. Policy makers and retail managers should be aware of income and expenditure impacts on consumer preferences. Food groups considered in this study are well-liked components of Sri Lankan cuisine; hence, households would not be expected to move away from these food groups as living standards advance. Thus, it is understandable why none of these food groups appear to be inferior. Expenditure elasticities are positive for all groups, with leafy vegetables recording the lowest value and dairy products the highest. Yams, meat, fish, dairy products, and fruits are found to be luxury commodities. Further, FAFH also can be identified as a luxury good.

These estimates of expenditure elasticities infer that Sri Lankans are less likely to access yams, meat, fish, dairy products, fruits, and FAFH, unless they achieve higher living standards as a result of real income or economic growth. Conforming to the dietary patterns of Sri Lankans, cereals, vegetables, and pulses indicate the lowest expenditure elasticities amongst the 12 food groups. As discussed above with respect to price elasticities, expenditure elasticities also highlight the dominant role played by cereals, vegetables, and pulses in Sri Lankan diets. This signifies that households tend to purchase these food groups, regardless of living standards and market prices.

3.2 Demographic, price, and expenditure effects on nutrient consumption

Insight into nutrient consumption of Sri Lankan households is useful for food industry managers, medical service providers, and policymakers. Nutrient elasticities with respect to demographic variables are presented in Table 5. Urban households are more likely to consume low nutrient levels compared to nutrient consumption of rural households. Percentage effects for intake of fats and carbohydrates report the largest differences between urban and rural residents. Households in estate regions, however, record higher intake of carbohydrates and lower intake of fats than their rural counterparts. With respect to ethnicity, both Sinhalese and Tamil households indicate relatively higher consumption for all nutrients than those of other ethnicities.

All nutrient elasticities with respect to adult equivalent are positive and statistically significant. For a 10% increase in adult equivalent, intake of carbohydrates, fats, and proteins are likely to increase by 1.32, 0.86, and 0.91%, respectively. The highest magnitude increase reported is for carbohydrates, which primarily come from cereals, a staple food in Sri Lanka. However, minute changes in nutrient intake can be expected as adult equivalent increases.

Table 6 shows nutrient elasticities with respect to food prices and expenditure, categorised for the entire population, poorest, and richest households. Nutrient elasticities with respect to price changes for most food groups are significantly negative. Since the quantity demanded for all food groups is found to be inversely

Table 5. Effects of demographic factors on nutrient consumption.[1,2]

Demo-graphic variables	Calories		Proteins		Fats		Carbohydrates	
	Parameter estimate	% effect	Parameter estimate	% effect	Parameter estimate	% effect	Parameter estimate	% effect
Urban	-0.11**	-10.08	-0.05**	-5.26	-0.14**	-13.20	-0.11**	-10.00
Estate	0.01	1.17	0.02	2.02	-0.12**	-11.50	0.09**	9.42
Sinhalese	0.20**	22.44	0.18**	20.08	0.21**	22.99	0.21**	23.82
Tamils	0.13**	13.54	0.10**	10.22	0.08**	7.88	0.15**	16.72
Adult equivalent	0.11**		0.09**		0.09**		0.13**	

[1] Significance levels at 1%**.

[2] Coefficients of adult equivalent present elasticities.

Table 6. Price and expenditure elasticities of nutrients.[1,2]

	Calories			**Proteins**		
	Population	**Poorest**	**Richest**	**Population**	**Poorest**	**Richest**
Constant	9.51**	10.45**	10.13**	5.00**	5.92**	5.76**
Prices						
Cereals	-0.29**	-0.35**	-0.17**	-0.24**	-0.30**	-0.14**
FAFH[3]	-0.08**	-0.14**	-0.06**	-0.08**	-0.15**	-0.07**
Pulses	0.00	0.02	-0.01	0.00	0.03	-0.01
Vegetables	-0.08**	-0.13**	-0.04*	-0.06**	-0.12**	-0.03
Leafy vegetables	-0.05**	-0.07**	-0.04**	-0.10**	-0.13**	-0.09**
Yams	0.01**	0.00	0.01	0.00	0.01	0.00
Meat	-0.13**	-0.13	-0.12**	-0.15**	-0.11	-0.14**
Fish	-0.10**	-0.16**	-0.09**	-0.11**	-0.19**	-0.07**
Dried fish	-0.07**	-0.14**	-0.05**	-0.08**	-0.17**	-0.04**
Coconut	-0.07**	-0.09**	0.01	-0.07**	-0.08**	-0.01
Dairy products	-0.04**	-0.03	-0.06**	-0.05**	-0.03	-0.08**
Fruits	-0.01*	0.00	-0.01	0.00	0.01	0.00
Food expenditure	0.67**	0.69**	0.48**	0.81**	0.84*	0.60**
	Fats			**Carbohydrates**		
	Population	**Poorest**	**Richest**	**Population**	**Poorest**	**Richest**
Constant	5.91**	7.63**	6.99**	7.66**	7.82**	8.41**
Prices						
Cereals	-0.26**	-0.42**	-0.10**	-0.38**	-0.42**	-0.25**
FAFH	-0.08**	-0.18**	-0.05**	-0.08**	-0.13**	-0.07**
Pulses	0.01	0.11*	0.00	0.00	0.01	-0.01
Vegetables	-0.05**	-0.11	-0.01	-0.11**	-0.18**	-0.07**
Leafy vegetables	-0.03**	-0.05**	-0.02**	-0.05**	-0.07**	-0.04**
Yams	-0.01	-0.02	0.00	0.01**	0.01**	0.01
Meat	-0.14**	-0.20	-0.11**	-0.13**	-0.09	-0.12**
Fish	-0.10**	-0.21**	-0.07**	-0.11**	-0.15**	-0.10**
Dried fish	-0.09**	-0.15**	-0.08**	-0.06**	-0.16**	-0.03
Coconut	-0.11**	-0.18**	0.05	-0.04**	-0.05	0.02
Dairy products	-0.06**	-0.08*	-0.08**	-0.03**	-0.01	-0.06**
Fruits	0.00	0.03	0.01	-0.02**	-0.02	-0.02**
Food expenditure	0.75**	0.79**	0.41**	0.69**	0.79**	0.48**

[1] Significance levels at 1%** and 5%*.

[2] Coefficients of prices and food expenditure present elasticities.

[3] FAFH: food away from home.

related to corresponding price changes, price upturns may diminish nutrient intake of households. However, consumption of all nutrients appears to be much less responsive to price changes in most of the food groups. It is evident that household food consumption heavily depends on substitutes, and consequently, households adjust food choices as prices vary. Because of the ability to endure these price changes through substitution, it is clear that households are more likely to gain necessary nutrients through any food available. Hence, nutrient intake is not sensitive to food price changes.

Conversely, nutrient intake tends to be affected by price changes in cereals and meat, in relatively higher magnitudes. Consumption of carbohydrates and proteins can be greatly affected by price increases in cereals and meat, respectively. Rice, a staple food in Sri Lanka, represents the majority of the cereals group and is a main source of carbohydrates. Similarly, meat is a rich source of proteins. Given that cereals and meat are responsible for notable shares of carbohydrates and proteins, respectively, substitution is more challenging. Moreover, the price of cereals is a major factor in determining carbohydrate intake in both poor and rich households. Due to high-priced protein sources, protein intake in rich households appears to be affected by price increases in meat, while price variations in fish and dried fish may influence the protein intake in poor households.

Expenditure elasticities for all nutrients are statistically significant at the 1% level. Proteins record the highest expenditure elasticity for the entire population, while calories indicate the lowest value. The high value for proteins is likely due to the consumption of rich protein sources, such as meat and fish, indicating a greater sensitivity to changes in expenditure. Hence, if communities experience diminished living standards, protein intake will be discouraged more than other nutrients. Additionally, a 10% reduction in expenditure decreases calorie intake by 6.74%. This implies that people may shift toward other affordable food choices such as cereals and vegetables, in order to obtain adequate energy. This is apparent from the expenditure elasticity of carbohydrates, which is the lowest value amongst the three macro-nutrients. This again represents the usual dietary pattern of Sri Lankans, where the majority of households consume rice for at least one meal per day. As a rich source of carbohydrates, rice compensates calorie intake when costly protein sources are not affordable.

High protein sensitivity is evident, not only in the population as a whole, but also at the poorest and richest expenditure levels. If living standards weaken by 10%, the poorest households will drop their protein consumption by 8.36%, while a 6.05% decline can be expected in the richest households. Therefore, although the poorest and richest may respond in different magnitudes as expenditure varies, proteins remain the least accessible nutrient for both groups.

Furthermore, consumption of all macro-nutrients in poor communities will be affected in relatively higher proportions than in wealthy communities. The percent change in the consumption of each nutrient is less than the percent change in expenditure. While the percent change is smaller, the poorest communities are still expected to be worse off as a result of hostile economies. Moreover, as expenditure increases, the richest households vary more in their consumption of proteins, fats, and carbohydrates than the poorest households. This finding infers that when consumers experience increased living standards during favorable economic times, a more imbalanced nutrient intake is expected to occur in wealthier households. As a result, these households may be more likely to continue imbalanced nutrient intake in the future, regardless of living status.

4. Conclusions, implications, and future research

This study provides insight into food and nutrient consumption in Sri Lanka. The QUAIDS is employed to examine the impacts of food prices and socio-economic characteristics on food and nutrient intake, respectively. Results suggest that policies aimed at improvement of household income levels, as opposed to price policies, may have greater nutritional impacts. Lower sensitivity to price changes was noted for cereals, pulses, vegetables, dried fish, and coconut. This finding indicates that these food groups are considered the most important in Sri Lankan dietary patterns. Policies aimed at manipulation of prices for these goods will likely have little impact, given that these commodities are Sri Lankan diet staples.

Conversely, price variation for more expensive food items, such as meat, has a large impact on consumption. Demand for other more expensive commodities including FAFH, leafy vegetables, yams, fish, dairy products, and fruits are also likely to exhibit a higher sway as prices fluctuate. Fruits and all animal source foods are found to be the most sensitive food groups to changes in expenditure. However, except for vegetables, leafy vegetables and meat, the magnitude of price elasticities for all food groups is less than their expenditure elasticity counterparts. Dairy products and fruits are found to have no substitutions; thus, high sensitivity to prices and expenditure may cause consumers to reduce or discontinue consumption when market and/or economic situations are unfavorable. Additionally, nutrient consumption of poor households is more responsive to food price changes than nutrient consumption of rich households, and expenditure greatly affects households' consumption of nutrients. This finding highlights the importance of emphasis on policies aimed at increasing household incomes, to enable easier access to such goods during times of economic distress.

Additionally, policy makers should focus on nutritional education, particularly for consumers located in certain geographic sectors, as sectoral impacts are evident in both food and nutrient consumption. Urbanites are most likely to consume price and expenditure elastic foods, yet this group frequently experiences low nutrient intake. Urban food outlets may take note of this and promote more healthy, affordable food choices in these regions. Ethnic disparities were not found to influence consumption of cereals, coconut, and vegetables; however, consumption of meat can be affected, which should be noted by retail outlet managers. Additionally, nutrient gain is found to be higher for Sinhalese and Tamils, as compared to other minor ethnicities.

Additional nutritional policy should consider availability and access to specific nutrient sources. Among macro-nutrients which provide energy, proteins are the least accessible to Sri Lankans. High rice consumption induces intake of carbohydrates, resulting in imbalanced carbohydrate/protein nutrient intake. Seasonal or short-term marketing and price promotions by food outlets may assist with alleviating this discrepancy. Additional impacts on calorie intake may be observed as a result of fluctuations in cereals and meat prices.

Demand for food and nutrients may exhibit diverse impacts under different income groups. Future research should consider estimating demand under disaggregated income levels. Further, consumption choices vary amidst intra-group food commodities that are substitutable with each other. In this regard, this study can be further extended to calculate elasticities in terms of disaggregated food commodities under each group, while incorporating demographic variables in the QUAIDS. In addition, not only macro-nutrients, but also micro-nutrients play a significant role in individuals' health and nutritional status. Given the current potential of unhealthy dietary habits, malnutrition, or under-nutrition, it would be useful to estimate elasticities for micro-nutrients as well.

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