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Does Agriculture Promote Diet Diversity? A Bangladesh Study

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1 Introduction

It is now widely recognised that intake of sufficient dietary energy — the most basic human need for survival — does not ensure adequate intake of protein and micronutrients necessary for leading an active and healthy life. Legumes, animal products, fruits and vegetables are important sources of minerals and micronutrients. Micronutrient deficiency causes impaired cognitive development, compromises immunity and increases vulnerability to infectious diseases and, in severe cases, even causes mortality. Recent studies show that the consumption of animal and fish products, which are dense in protein and micronutrients, has a higher correlation with nutritional status than does energy consumption (Smith 2004b). Thus, to improve the nutritional situation it is crucial that we address issues of dietary quality in addition to those of dietary quantity.

Bangladesh has made commendable economic progress in recent years with acceleration of the growth rate from 3.5 per cent per year during 1971-89, to 5.0 per cent in the 1990s, and at 6.2 per cent over the last decade. With reduction of population growth from 2.35 per cent per year in the 1970s to 1.21 per cent in 2015, the per capita income growth has also accelerated from a meagre 1.2 per cent during the first two decades after Independence to 4 per cent per year over the last decade. The growth has made positive impact on reduction of poverty from 58 per cent in 1990 to 32 per cent in 2010 (BBS 2011). Agricultural growth has also accelerated from about 2.0 per cent per year in the 1980s to 3.0 per cent in the 1990s and about 4.0 per cent in the last decade (however, the rate has been declining since 2010). There has been considerable diversification in agricultural income, with the share of crop production declining from 65 per cent to 56 per cent and the share of fisheries increasing from 12 to 22 per cent.

But the rate of decline in undernutrition and malnutrition has not been matching with economic and agricultural progress. The persistence of undernutrition is considered a serious public health problem in Bangladesh. Approximately 60 per cent of childhood deaths in Bangladesh are due to malnutrition or undernutrition as underlying causes (Faruque et al. 2008). The level of stunting that stood at 41 per cent in 2011 has declined by only 1.4 percent per year over 2004-2011, and the proportion of underweight children has declined by only 0.7 per cent per year to 36 per cent in 2011. The pattern of change in wasting has been small and inconsistent (BDHS 2011). Deficiencies of micronutrients are widespread in Bangladesh and there are four that are of particular relevance to public health: vitamin A, iron, iodine, and zinc. Especially serious is the problem of iron deficiency that causes anaemia. Surveys conducted in 2003-04 show that 92 per cent of 6-11 month-old infants in Bangladesh suffer from anaemia due to iron deficiency (Rashid et al. 2010). The prevalence remains high in pre-school children (68 per cent) and adolescent girls (40 per cent). Four out of ten pregnant women still suffer from anaemia, particularly in rural areas. This high burden of anaemia impacts on the economy of the country; an estimated 7.9 per cent of the gross domestic product in Bangladesh is lost due to iron deficiency alone (Horton and Ross 2003).

In Bangladesh, the nutrition issue tends to be addressed through its proximal or underlying determinants such as dietary intake, feeding practices, health status and so on. The roles of broader determinants such as agriculture that determines the composition of the diet and wider economic factors such as socio-economic characteristics of households as well as that of other non-food environments are relatively neglected. Taking that view into consideration, this paper aims to estimate the recent changes in diet diversity from the detailed food intake data estimated from the household income and expenditure surveys and analyze the drivers of change, including the level of income and the sources of income such as agriculture.

Section 2 provides a review of existing literature as a guide to develop a model for determinants of dietary diversity. Section 3 explains the sources of data and the method of estimating diet diversity, and the empirical model for explaining diet diversity. The findings of the study are presented in Section 4.

2. Conceptual Issues

Studies abound on the determinants of consumer demand for dietary energy (or dietary quantity) consumption, but few of them pay attention to the demand for household dietary diversity or diet quality that influences food and nutrition security. Ruel (2001) finds a positive effect of income on dietary quality. Theil and Finke (1983), using cross-sectional data for 30 countries, show that dietary diversity increases with growing per capita real income. Estimation of cross-country Engel curves indicates that the number of foods consumed increases, and the concentration of expenditure decreases, with increasing per capita income (Falkinger and Zweimüller 1996). Pollack (2001) and Regmi (2001) also confirm that the demand for fruits and vegetables rises with income.

However, the proposition that income growth will reduce malnutrition is still debated. As incomes rise, expenditure on food may increase because more expensive food is being purchased, but the nutrient content of these foods may not increase proportionately (Pitt 1983; Behrman et al. 1988). Brinkman et al (2010) and Behrman and Deolalikar (1987) analyse the role of income in nutrition improvement and find that improvements in income can trigger growth in food expenditures or total calorie intake, but this may not coincide with a diet more rich in proteins and minerals.

So, what are the other factors that could play important roles in improving dietary diversity? A number of studies have documented the importance of women's education in improving nutritional status, especially that of women and children (Smith and Haddad 2000; Smith et al. 2003). A study in Indonesia finds that mothers with greater nutrition knowledge allocate a larger share of their food budget to foods that are rich in micronutrients, including fruits and vegetables (Block 2003). These studies suggest that it is important to distinguish between women's and men's education in understanding the determinants of dietary quality.

Bouis and Novenario-Reese (1997), using their survey data from Bangladesh (with individual level dietary intake data), measure the determinants of calorie, iron, vitamin A, vitamin C and fat intake and conclude that demographic variables like the sex and the level of education of the household head have significant effect on nutrient intake. They find that in Bangladesh the main determinants of the demand for micronutrients, besides income, are: education, occupation, gender of the household head, household size, food prices, and age-sex composition of household members. Rashid D. et al.

(2006) similarly suggest that the crucial determinants of dietary quality (represented by protein intake and DDS) in Bangladesh are: income, female and male education, gender of household head, the prices of rice, fish, eggs, dairy products and edible oils, and household size and demographic composition. A significant role is also found for seasonal variation associated with the agricultural cycle.

However, very few studies have attempted to shed light on the agriculture-nutrition linkage (connecting or disconnecting) and whether involvement with agricultural production as well as more diversified agricultural production have any effect on a household's diet diversity or not. The conceptual framework developed by the TANDI (Tackling the Agriculture-Nutrition Disconnect in India) initiative emphasised seven pathways through which agriculture may influence nutrition (Gillespie et al. 2011). The most direct pathway highlights agriculture as a source of food translating into consumption (via crops cultivated by the household). Second, monetary returns come via wages or marketed sales of food produced by agricultural workers. Third, the relationship between agricultural policy and food prices involving a range of supply-and-demand factors ultimately leads to the prices of various marketed food and non-food crops. The fourth pathway emphasises how income derived from agriculture is spent for non-food items such as health, education and social welfare — those indirectly impacting the nutritional status. The remaining three pathways particularly talk about how agriculture intensifies different dimensions of women's status in relation to empowerment: their ability to influence household decision making, intra-household allocation of food, in tackling health issues, care and feeding of family members, children's health and nutrition as well as their own nutritional status. Various studies (Subramanian and Deaton. 1996; Neeliah and Goburdhun 2006) point out that the relationship between broad-based economic growth and nutritional outcome may depend on the composition of economic and agricultural growth as well as on other conditional factors such as water, sanitation and hygienic practices, socio-economic inequality and women's empowerment. Thus the association of a household's access to better water, sanitation and infrastructure with its nutrient intake needs to be considered in any model that aims to explain the link between agriculture's importance as a source of income and diet diversity and nutritional quality.

In developing an empirical model to show the association of agriculture with diet diversity, we have taken into account the findings of the above studies.

3. Data and Methodology

3.1 Sources of data

The Bangladesh Bureau of Statistics (BBS), the organisation in charge of generating official statistics, conducts household income and expenditure surveys (HIES) to collect detailed data on consumption of different food items, other major expenditures, the sources and composition of income, and detailed household characteristics. The sample households are drawn from the data using a proportionate random sampling method separately for rural and urban areas. The data are used to measure progress in income distribution, poverty and socio-economic wellbeing for various geographical regions. HIES data for the years 2000 and 2010, collected using a two-stage stratified sampling design, have been utilised in this paper. The entire country was divided into five divisions in 2000 and six divisions in 2010. Each division has been segmented into three geographical regions: rural areas, urban municipalities and statistical metropolitan areas (SMAs). In the first stage of sampling, a number of primary sampling units (PSUs) were chosen with probability proportionate to the size of the division. In the second stage, 20 households per PSU were selected, except in all the SMAs where only 10 households were interviewed. The total sample size was 7440 households in HIES 2000 and 12240 in HIES 2010. With such a complex sampling design, it is important to correct for the design effect so that any calculated statistics apply to the population group of interest (Deaton 1997). For the correction of the sampling design, sampling weights and variables delineating the strata and PSU for each household provided with the survey have been used in each year.

3.2 Characteristics of data on food acquisition

Data were collected on households' food consumption of 137 items in 2000 and of 147 items in 2010. Collected data include quantity, source and value (in Bangladeshi currency) of food consumption. Data were collected on food purchases, consumption of food from home production, and food received as wages and gifts. The recall period was two days for all food items except spices, for which the recall period was one week. Each household was visited every alternate day in a fortnight (7 times in 14 days) to collect information on food acquisition. Similarly, households were visited at the weekend to collect information on spice consumption. In order to capture the seasonal variations in food acquisition, the survey was conducted throughout the year in batches of a number of households.

Quantities of foods acquired were recorded directly in metric units (grams) except for a few items where they were recorded either in "units" (for example, number of eggs). For a few generic food items, the households were asked to report expenditures on food acquired and the average price from which the quantity acquired was derived. Metric quantities available from pre-existing databases, such as the United States Department of Agriculture Nutrient Database for Standard Reference, Release 15 (USDA 2003) or other surveys were used to get the quantities when the data were recorded in units. When the data were recorded in volumetric measures (millilitres), specific gravities from the Australia-New Zealand Food Composition Table were used to convert to metric weights.

Household expenditure surveys can be subject to non-sampling errors — from reporting on the part of households to recording on the part of enumerators to entering on the part of data entry operators (Smith 2004a). To minimise the errors, rigorous cleaning of the data was undertaken in three stages. First, for each food, metric unit values (expenditure divided by metric quantities) were cleaned manually by examination for outliers at both ends of the distribution. When outlying unit values were detected, both the expenditure and quantity used to calculate them were set to missing values. Second, metric quantities of individual foods were cleaned. Any quantity per household adult equivalent that was more than three standard deviations from the sample median value was set to missing. Households for which at least one food quantity could not be estimated were dropped from the sample. Third, metric quantities set to missing in the first and second stages were replaced with an estimated value using OLS regression.

3.3 Measuring dietary diversity score and nutrient intake

The household-level dietary diversity score (DDS) is defined as the number of different foods or food groups consumed over a given reference period (Hoddinott and Yohannes 2002; Swindale and Bilinsky 2006; Gina et al. 2007). DDS estimates a household's economic ability to consume a set of nutritionally diverse food items. In this study, we define dietary diversity score as the number of food groups, out of 7, that on average a household acquired over the survey reference period. These groups are: cereals; roots and tubers; pulses and legumes; animal products; vegetables; fruits; and edible oils and fats. If the household acquired an item from a particular food group, we assign a value "1" for that food group and "0" otherwise. We measured the household DDS (out of seven) for each of the 14 days and then obtained the average for the 14-day period. The value of the score thus varies from 1 to 7.

We used FAO's nutrient conversion table to convert the food intake data into adult equivalent energy, protein, fat, iron, zinc and vitamin A intake of the household. To construct this measure, the cleaned metric quantities of foods acquired by households were multiplied by the edible potion coefficients of each of the foods and then multiplied by the food's energy (kcal), protein, fat, iron, zinc and vitamin A value, which is finally divided by the number of days in the reference period and the number of adult equivalents. This gives the per day per capita nutrient intake of households.

3.4 Measuring food consumption score

Despite the fact that dietary diversity helps capture the nutritional scenario, it is merely a qualitative figure. In order to capture a relatively accurate scenario, a more sophisticated tool needs to be designed. The food consumption score (FCS) formulated by the World Food Programme provides the solution to that. This basically refers to a proxy indicator based on weighted frequency of food consumption of eight different groups.[1] The empirical formula for calculating the food consumption score can be expressed as:

$FCS = a_1x_1 + a_2x_2 + \ldots + a_8x_8$,

Where i=food group, x=frequency, a= weight

As the HIES data contains the consumption record for two consecutive weeks, we have taken average food frequency for the same. For example, if rice is consumed for 7 days in the first week and for 6 days in the second week, the average food frequency for rice becomes 6.5. The total food consumption score is then calculated by summing up the product of the respective food frequency and the weight assigned to that particular food group. The maximum value of FCS can be 112 which can be attained if the household had consumed all of the 7 food groups in each day of the two weeks.

[1] Food Consumption Score Overview, March 2012

3.5 Choice of independent variables

The diet diversity score was taken as the explanatory variable for this study. Although we estimated the micronutrient intake from the data (see descriptive graphs) for each household for the two reference years, we refrained from undertaking investigation on their determinants because of several reasons:

- Such studies were undertaken earlier based on sample household- and member-level food intake and nutrition data that generated adequate knowledge on the subject.
- Our derived data on nutrient and micronutrient content are at the household level, but the requirement for these components vary by age-sex composition of the members of the household and specific physical conditions such as pregnancy. So studies of their determinants might not be meaningful.
- Dietary diversity has long been recognised by nutritionists as a key element determining high-quality diets and studies on its determinants are lacking in general for developing countries and particularly for Bangladesh. A more diversified diet is associated with a number of improved outcomes in areas such as birthweight, child anthropometric status and improved haemoglobin concentrations (Swindale and Bilinsky 2006). Indeed, studies from both developing and developed countries give evidence of a strong positive association between diet diversity and nutrient adequacy (Ruel 2001), so drivers of diet diversity may also be important in explaining nutritional adequacy.

According to Hoddinott (1999), dietary diversity is gaining importance in nutritional literature as more importance is given to dietary quality over quantity. Using correlation coefficients, contingency table and regression prediction methods to establish the association of DDS with per capita calorie consumption, he found a reasonably good correlation and a predictability in level and distribution of food security. In their 2002 study, Hoddinott and Yonannes argue that dietary diversity is associated with a number of improved outcomes and document other studies that find association between DDS and birthweight (Rao et al. 2001); child anthropometric status (Allen et al. 1991; Hatloy et al. 2000; Onyango et al.1998; Taren and Chen 1993; Tarini et al.1999); improved haemoglobin concentrations (Bhargava et al. 2001); reduced incidence of hypertension and reduced risk of mortality from cardiovascular disease and cancer (Kant et al.1995).

In their systematic review, Vinas et al. (2009) list a number of studies showing the relationship between dietary quality and nutrition adequacy. Mirmiran et al. (2006) study the appropriateness of DDS to assess nutrient adequacy for Iranian women and findthat DDS correlated with Ca, P and vitamin B_2 and Zn adequacies. In addition, Mirmiran et al. (2006) evaluate DDS as an indicator of nutritional adequacy among 304 adolescents in Tehran. The mean adequacy ratio (MAR) reflected the nutrient adequacy ratio of twelve nutrients (vitamin A, riboflavin, thiamin, vitamin C, Ca, Fe, Zn, P, Mg, protein, K and fat). Steyn et al. (2006) assess whether DDS is a good indicator of nutrient intake adequacy for a sample of 2200 children aged 1-8 years and find a high correlation between DDS and MAR and also that DDS is correlated with the adequacy of vitamins A, B_6, B_{12}, C, and Ca, folic acid, Fe, niacin, riboflavin, thiamine and Zn.Torheim et al. (2003) use DDS and MAR as diet quality indices and find different correlation coefficients for males and females, concluding that both indices are relatively good indicators for nutrient adequacy among males. Thus we thought it would be justified to analyse the drivers of household dietary diversity index.

In our model, the list of dietary diversity determining variables includes division dummy to capture the regional fixed effect (culture, people's food preferences, resources available in the area). Dummy variables are also included for month of interview to capture the seasonal variations in dietary patterns in Bangladesh that follow the agricultural production cycle (Smith and Subandoro 2006), which also influences the prices and availability of foods. We included dummy variable indicating the location of household, sex of household head, education of head, education of spouse (to capture the importance of nutritional knowledge in better quality foods and thus nutrition); household size (to capture the possible scale effect); price of rice and food price index (to capture the price effect on consumption of non-rice foods) and the non-food environment such as use of sanitary latrines (good sanitation), use of safe water and availability of electricity (a proxy for infrastructure development).

The main point of interest for this study is the effect of agricultural income and its composition on dietary diversity. One may argue that the level and the composition of the intake of different food items would be determined by the level of per capita income of the households and the prices of different food items. It does not matter from which source the income is derived. If enough food is available in the market and the prices are affordable, the household can purchase the preferred amount even if the household members do not produce the food in the family farm. A contrary argument is that under certain circumstances the cost of producing food in the owned farm may be lower than the cost of acquisition from the market, and those who produce the food may consume higher amounts than those accessing the food from the market. The food produced from animal sources contains high quality protein and micronutrients. So households engaged in animal production (the higher the proportion of income derived from livestock farming) may have higher dietary diversity with a larger proportion of quality food items in their food basket. In order to test the hypothesis, we included the relevant income variables in the model for diet diversity.

3.6 Measuring farming diversity index

Agricultural involvement of the household is crucial for the nutrition intake of the household members. More often than not, a household involved in diversified agricultural activities has the probability of having a higher dietary diversity or food consumption score. That is why we have constructed an index, the farming diversity index that takes into consideration the agricultural involvement of a household. The index is calculated on the basis of 13 different categories of agricultural farming viz., cereals, pulses, oilseeds, potato, leafy vegetables, other vegetables, fruits, tubers/roots, fisheries, meat, eggs, milk and cash crops. If a household is involved in producing and farming a definite category, the score for that particular group is considered as 1. Zero is assigned to those households who aren't involved in the agricultural farming of a category. Thus we have calculated the cumulative score for all the groups.

3.7 The empirical model

To model the household behaviour we used the framework of Bergson-Samuelson social welfare function. Households follow some bargaining process to maximise utility of the members subject to nutrition provisioning functions, budget constraints and full-income constraints. Following Smith (2004b), the utility functions can be specified as

$$U_i = U_i(N_1, \dots, N_1, F_1, \dots, F_k, X_0, T_L), i = 1, \dots, I,$$

Where the N_i, i=1…I are members' nutrition provisioning functions, the F_k, k=1…K, are individual foods consumed by each member, X_0 is non-food commodities and services consumed, and T_L is leisure time. Nutrition provisioning is the process through which goods, especially food, are combined with care time to provide for a person's nutritional health or status. The nutrition provisioning functions is

$$N_i = N_i\big(Z_1, \dots, Z_j, X_{NO}, T_N, \Omega_N\big), i = 1, \dots I$$

where

$$Z_j = Z_j(F_1, \dots, \mathrm{F}_K), j = 1, \dots J$$

Here the Z_j, j=1,…,J are nutrients, such as calories, proteins and fats (the macronutrients) or vitamin A, zinc, and iron (micronutrients), all of which are derived from foods. The variable X_{N0} is non-food inputs into nutrition provisioning (e.g., medicines), T_N is time spent in nutrition provisioning (e.g., feeding a child), and the vector Ω_N contains relevant individual, household and community characteristics.

The reduced form nutrient demand function is as follows:

$$Z_j^* = (P_F, P_O, W, E, \Omega_N), j = 1, \dots J$$

where PF and Po are vectors of food and non-food prices, respectively, W is a vector of household members' wages (incomes), and Ω_N is a vector of exogenous variables.

In order to explain the nutritional status of the household, we have run separate regressions on separate dependent variables for the years 2000 and 2010. As mentioned earlier, the dietary diversity index and food consumption score have been used as dependent variables in separate regression equations. Moreover, we have estimated the model at both the national and rural levels, which offers us a useful juxtaposition of estimated value of coefficients for better interpretation.

For modeling dietary diversity, we have divided the foods into 7 different categories, viz., cereals, pulses and legumes, roots and tubers, animal products (meat, eggs and milk), vegetable, fruits, and oil and oilseeds. As we have data for a large sample size and the diversity index exhibits continuous form, ordinary least square fits the model well. Similarly, the regression on food consumption score has been run using the ordinary least square method.

Notwithstanding this, the explanatory variable 'household income' included in both the sample regression functions suffers from endogeneity which can be imputed to omitted variable bias. Using an 'instrumental variable' is widely regarded as an effective tool to get rid of prevailing endogeneity. We have used two instrumental variables — 'number of male members who belong to working age' and 'number of female members who belong to working age' and thereby instrumented the endogenous variable 'household income'. As we have deployed instrumental variables in our analysis, the "two stage least square" (2SLS) method has been applied.

4. Results and Discussion

4.1 Changes in dietary diversity, food consumption score and nutrient intake (2000 to 2010)

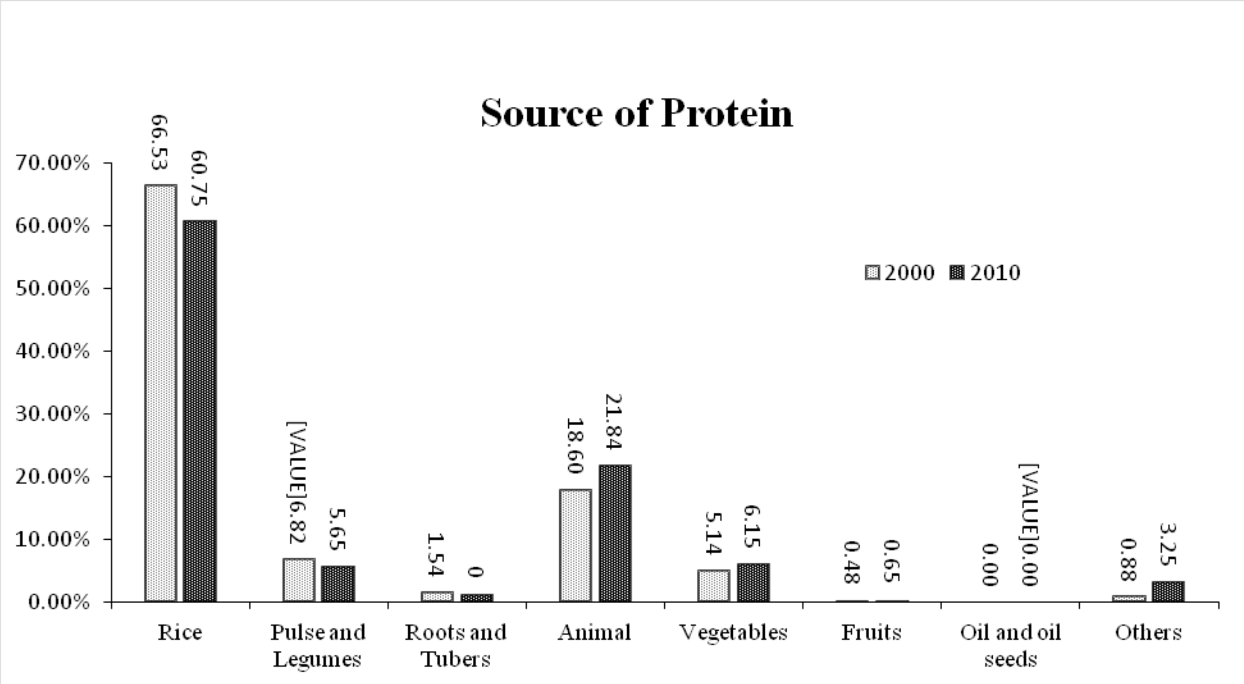
Table 1 presents the findings on changes in dietary diversity and micronutrient intakes of different nutrients over 2000 to 2010. Average DDS registered a decade-long progression. The diversity score was low at 4.82 in 2000 and increased to 4.95 in 2010. The adult equivalent energy consumption, however, did not have a linear trend. The per capita calorie intake declined marginally from 2354 kcal in 2000 to 2344 kcal in 2010. The decline in energy intake reflects a trend in the reduction in per capita rice consumption that has started in recent years (at 1.7 kg per person per year during 2000-2010). The protein intake saw a modest rise over the period 2000-10 that reflects respectable improvement in diet quality. Fat intake also registered a steady progression over this decade. Vitamin A is an indispensable micronutrient. Insufficient supply of vitamin A causes child blindness. Bangladesh has made good progress in reducing vitamin A deficiency through supplementation with vitamin A capsules. From the food intake data, we find an increase in vitamin A intake from 215 to 308 mcg per person per day, an increase of nearly 50 per cent over the ten year period. Zinc is an important mineral that acts as an inhibitor of diarrhoeal diseases and contributes to the development of cognitive ability of the children. However, the consumption of foods rich in zinc registered a downward trend throughout the decade. This is an issue of serious health and nutrition concern.

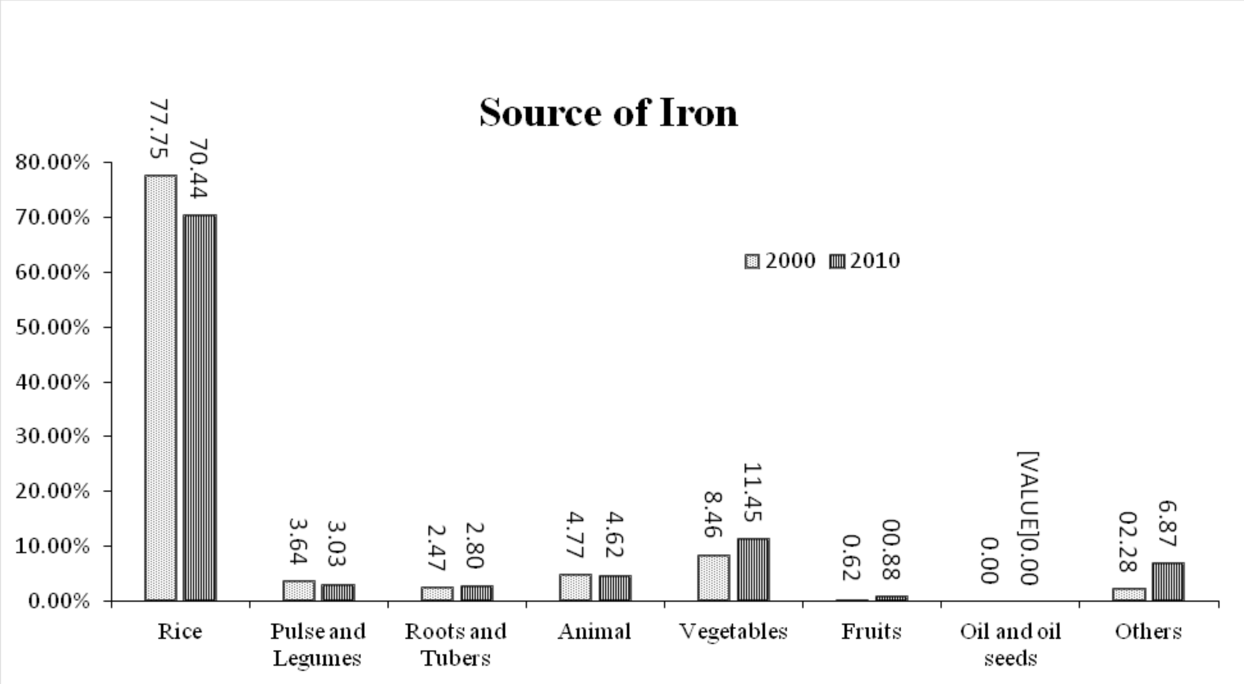
Table 1: Trends in DDS and micronutrient intake over the decade (2000-2010)

Variables	2000	2010
Dietary diversity index (with range 1 to 7)	4.82	4.95
Food consumption score	63.7	58.2
Energy (Kcal/per day per capita)	2355	2344
Protein (gram/per day per capita)	67.7	70.1
Fat (gram/per day per capita)	34.3	34.1
Vitamin A (microgram/per day per capita)	215	308
Iron (milligram /per day per capita)	33.2	34
Zinc (milligram/per day per capita)	16.2	15.8

Source: Derived from household level food acquisition data reported in HIES of the Bangladesh Bureau of Statistics.

Figure 1: Importance of different food groups as sources of protein, iron and zinc for the years 2000 & 2010





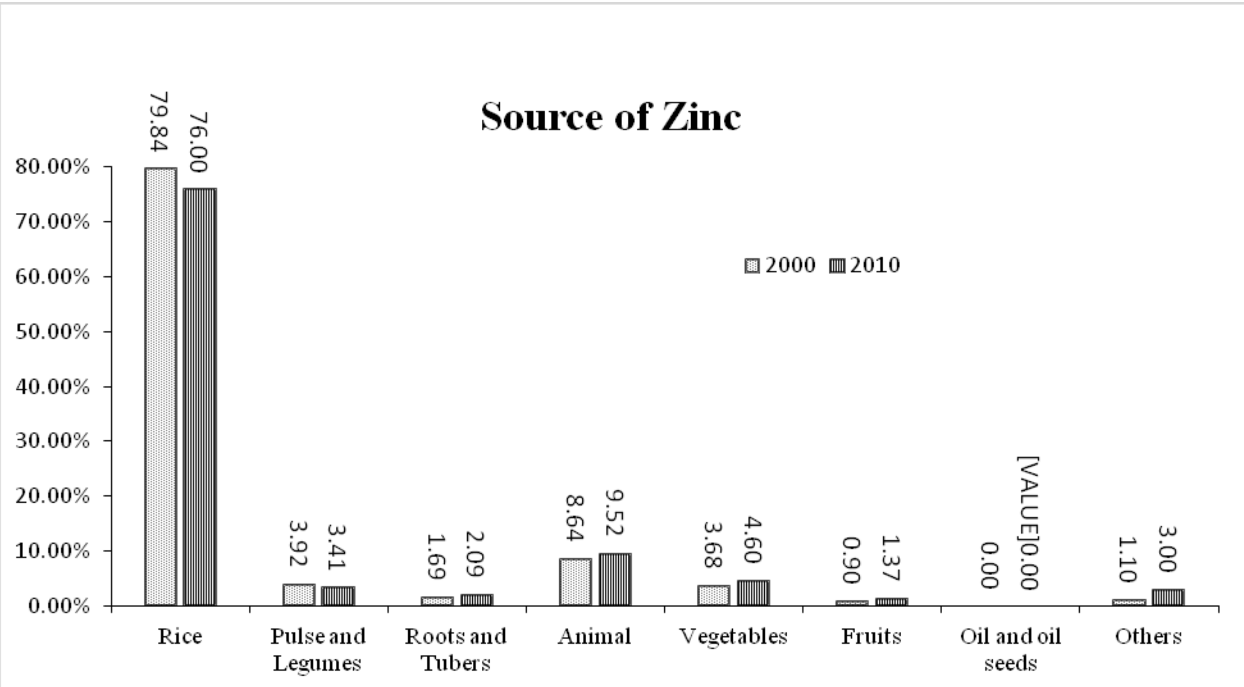


Figure 1 shows the change in the sources of protein, iron and zinc, the three important quality nutrients. It may be noted that though rice is still the major source of these nutrients, its importance in providing these nutrients has declined over time. Animal products have assumed more importance in providing protein, while vegetables have assumed significance in providing iron. The reduction in rice intake has had a negative impact on zinc availability. But it has not been compensated by the

increase in the consumption of animal products and vegetables that are other important sources of zinc.

4.2 Drivers of diet diversity: Results of regression analysis

The change in the major explanatory variables of diet diversity used in the model and their variance is reported in **Table 2**. It may be noted that the sample population living in urban areas has increased from 32 per cent in 2000 to 36 per cent in 2010. The number of members per household has reduced substantially from 5.2 in 2000 to 4.5 in 2010, a reflection of rapid progress made in fertility control. Some progress has also been made in the literacy levels. The average year of schooling for the household head has increased from 3.4 years to 3.9 years over the decade. For the spouse, the progress has been even better, from 2.4 in 2000 to 3.4 in 2010. Improvement in the educational attainment of the spouse is an indication of some headway made in women's empowerment. The major determinants of income for the household are the ownership of assets, the number of working members, and the level of education of workers. The ownership of land, the most important asset in rural areas, has hardly changed despite rapid rural-urban migration of the population. The average size of land ownership per household has increased from 0.86 to 0.90 acre over 2000 to 2010.

Table 2: Mean and variance of major explanatory variables for diet diversity, 2000 and 2010

Variables	2000		2010	
	Mean	Std. Dev.	Mean	Std. Dev.
Urban households (percentage)	32%	0.47	36%	0.48
Female-headed households (percentage)	9%	0.29	14%	0.35
Education of household head (year)	3.43	4.36	3.86	4.49
Education of household head's spouse (year)	2.36	3.59	3.41	4.05
Literacy of household head (percentage)	45%	0.49	50%	0.5
Literacy of the spouse (percentage)	36%	0.48	40%	0.49
Household size (number)	5.18	2.2	4.54	1.89
Land owned (acre)	0.86	4.53	0.9	2.41
Monthly household income (in thousandsTk)	6.16	18.13	12.02	16.92
Price of rice (Tk)	12.51	1.81	33.22	4.32
Household Involvement in different agricultural activities (%)				
Agricultural production	58%	0.49	68%	0.47
Crop production only	22%	0.41	22%	0.41
Both crop and livestock	20%	0.4	25%	0.43
Crop, livestock and fisheries	3%	0.17	6%	0.24
Household living conditions and infrastructure				
Use safe drinking water (percentage)	88.15%	0.32	85%	0.37
Have electricity connection (percentage)	37.31%	0.48	58%	0.49
Use sanitary latrine (percentage)	23.02%	0.42	37%	0.48

Source: Derived from household level data reported in HIES of 2000, and 2010, Bangladesh Bureau of Statistics

With regard to the non-food environment, the achievement in good sanitary practices in 2010 still remains low at 37 per cent of the households using sanitary latrines, only a marginal improvement over the rate of 23 per cent achieved in 2000. Bangladesh has achieved respectable progress in the use of safe drinking water with 88 per cent of the population having access in 2000, but the HIES data show some deterioration in this respect in 2010. We have used the access to electricity supply as a proxy measure for infrastructure development. The number of households having access to electricity has increased from 37 to 58 per cent over the decade, indicating substantial progress in this regard.

The growth in household income has been respectable, from US$ 1,354 per household per year in 2000 to US$ 2,240 in 2010, an increase of 65 per cent over the 10-year period. The income growth should have increased the capacity of the households to move from a predominantly cereal-based diet to a diet composed of better quality nutritious foods which are high in terms of calorie provision compared to cereals. Nearly two-thirds of the households earned some income from agriculture in 2010, an increase from 58 per cent in 2000. There is however a lack of specialisation in agriculture. Households who are exclusively engaged in cereal production were recorded in HIES at only 15 per cent, another 17 per cent were engaged in both crop and livestock production activities.

4.3 The drivers of diet diversity and food consumption score: The estimate of the model

Table 3 reports the results of the estimated model on the basis of 2SLS regression. In order to obtain unbiased and consistent parameter estimates, we instrumented income by constructing instruments based on the number of male and female members of working age. The Dhaka division has been used as the reference division for divisional dummies. In case of month dummies, the month of June has been considered as the reference month. Price index simply represents the ratio of 'price of rice' to 'price weight'

Table 3: 2SLS ordinary least square regression estimates for dietary diversity index
Level of significance: *** p<0.01, ** p<0.05, * p<0.1

Independent Variables	2000		2010	
	National	Rural	National	Rural
Annual household income (in thousands Tk)	0.01***	0.01***	0.004***	0.0037***
Chittagong	0.07***	0.07*	0.23***	0.29***
Rajshahi	-0.19***	-0.25***	-0.03	-0.05**
Khulna	-0.33***	-0.23***	0.23***	0.19***
Barisal	-0.37***	-0.31***	-0.17***	-0.12***
Sylhet	-0.29***	-0.25***	0.11***	0.05**
Month of January	-0.09**	-0.26***	-0.29***	-0.47***
Month of February	-0.28***	-0.19***	-0.19***	-0.09***
Month of March	-0.25***	-0.27***	-0.17***	-0.08**
Month of April	-0.16***	-0.31***	-0.13***	0.01
Month of May	-0.11***	-0.24***	0.08**	0.27***
Month of July	0.005	-0.10**	-0.07**	-0.15***
Month of August	-0.27***	-0.25***	0.24***	0.14***
Month of September	-0.21***	-0.35***	-0.30***	-0.18***
Month of October	-0.19***	-0.33***	-0.25***	-0.28***
Month of November	-0.27***	-0.47***	-0.50***	-0.42***
Month of December	0.15***	0.10**	-0.30***	-0.31***
Female-headed household	-0.16***	-0.20***	-0.08***	-0.09***
Educational qualification of household head	0.02***	0.01***	0.0004	0.003
Educational qualification of the spouse	-0.01***	-0.01	0.005**	0.01**
Price index (relative to price of rice)	0.03***	0.04***	0.01	0.04**
Land ownership	-0.0005***	-0.0006***	-0.0002***	- 0.0002***
Value of non-land asset (in thousands Tk)	-0.01***	-0.002***	-0.001***	-0.0004**
Access to safe drinking water	-0.07**	0.01	0.04**	0.03
Access to electricity connection	0.28***	0.23***	0.11***	0.08***
Access to sanitary latrine	0.07***	0.06**	0.01	-0.01
Remittance in taka (dummy)	-0.08***	-0.12***	-0.26***	-0.18***
Farming diversity index	0.03***	0.03***	0.01***	0.02***
Intercept	4.32***	4.26***	4.35***	4.16***

The average dietary diversity index for the years 2000 and 2010 has been regressed on the basis of the listed variables. Separate regressions have been run for the national and rural levels. Findings from the regression obviously suggest thatdiet diversity is positively associated with income. The ‘division fixed effect’ was significant in most cases, which reflects the fact that the locations of the households matter in influencing diet diversity, presumably because of difference in food preferences due to geographical location and cultural influence on the choice of the food basket. Assuming June as the reference period, month dummies have been introduced to capture the seasonal variation of the average dietary diversity index.

Apart from regional and seasonal variations, the coefficients of female-headed households, land ownership, value of non-land assets, and access to electricity connections are found to be statistically significant. Coefficients for the rest of the variables show a somewhat mixed picture. The coefficients for the variable educational qualifications of household head as well as access to sanitary latrines were significant for the year 2000 at both national and rural levels, whereas they appear to be insignificant for the year 2010. On the other hand, coefficients for foreign remittance (dummy) and educational qualification of the spouse were insignificant in 2000 but found to be significant in the year 2010.

In 2000, female-headed households experienced a lower DDS (ranging from 0.1 to 0.2 unit approximately) than male-headed households at both national and rural levels. In Bangladesh, women usually have less mobility than their male counterparts (social and cultural norms). Women who manage the household (some of them are widows, separated or divorced and without any male earning member) are not necessarily more empowered. Absence of adult male members, lack of participation in marketing, and seclusion within the household might account for the lower DDS for the female-headed households. The situation has somewhat improved in 2010 where female-headed households had, on an average, a DDS which is 0.1 unit lower than male-headed households at both national and rural levels. This improvement can be attributed to women empowerment at the rural level both by government- and NGO-led programmes. The findings also show that an increase in the price of rice induce households to reduce rice consumption and allocate more income to acquisition of non-rice foods, leading to higher diet diversity.

The main hypothesis that we wanted to test is whether the household’s involvement with agriculture, even after controlling for all other factors, will have a positive association with its dietary diversity. The coefficient of the farming diversity index representing the household’s engagement in agriculture is found positive and statistically significant for both years. We can therefore accept the hypothesis that involvement in agricultural activity promotes diet diversity. Other things remaining constant, one unit increase in the diversity index will induce 0.03 unit increase in the average dietary diversity at both national and rural levels for the year 2000. The value of the coefficient becomes 0.01 and 0.02 at national and rural levels, respectively, for the year 2010. Thus, agriculture and its diversity play a pivotal role for leveraging diet diversity and hence impact nutritional outcomes.
The food consumption score has been regressed on the basis of the same variables as listed in **Table 3**. **Table 4** shows the estimated values of the coefficients.

Table 4: 2SLS Ordinary least square regression estimates for food consumption score

Level of significance: *** p<0.01, ** p<0.05, * p<0.1

Independent Variables	2000		2010	
	National	Rural	National	Rural
Annual household income (in thousands Tk[!])	0.19***	0.17***	0.09***	0.07***
Chittagong	3.49***	0.37	5.03***	4.47***
Rajshahi	-11.34***	-13.58***	-6.10***	-7.56***
Khulna	-10.99***	-10.86***	-1.73***	-4.05***
Barisal	-9.34***	-8.52***	-4.80***	-4.54***
Sylhet	-3.94***	-1.39	5.34***	3.40***
Month of January	0.28	-3.55***	-4.69***	-5.32***
Month of February	-5.04***	-2.70**	-5.67***	-2.78***
Month of March	-2.97***	-3.47***	-3.51***	-1.07
Month of April	-5.41***	-7.06***	-2.86***	0.74
Month of May	-2.85***	-4.59***	1.25	4.90***
Month of July	1.06	0.05	-1.45*	-2.66***
Month of August	-3.89***	-2.78***	8.08***	7.30***
Month of September	-2.84***	-4.75***	2.32***	6.84***
Month of October	-0.79	-1.21	-1.81***	-1.74**
Month of November	-1.88**	-4.18***	-2.85***	-2.17**
Month of December	6.23***	5.79***	-4.21***	-4.10***
Female-headed household	-1.62**	-2.25**	-0.89*	-1.49**
Educational qualification of household-head	0.48***	0.43***	0.15***	0.23***
Educational qualification of the spouse	0.16*	0.28**	0.39***	0.32***
Price index (relative to price of rice)	0.51***	0.64***	-1.14***	-0.69*
Land ownership	-0.01***	-0.01***	-0.002*	0.002
Value of non-land asset (in thousands Tk[!]))	-0.11***	-0.03	-0.02***	-0.005
Access to safe drinking water	-1.08*	-0.64	0.5	-0.07
Access to electricity connection	7.70***	6.15***	4.12***	4.19***
Access to sanitary latrine	4.07***	4.20***	1.64***	1.19**
Remittance received in Tk (dummy)	1.47*	0.08	-2.67***	-0.87
Farming diversity index	1.39***	1.37***	0.20***	0.61***
Intercept	50.85***	51.49***	52.41***	49.82***

Note: $1=80 taka.

Like that of **Table 3**, the divisional and seasonal dummies exhibit significant values in most cases, suggesting that the location of the household and the seasonal variation have substantial effect on the variation of the food consumption score. Coefficient for female-headed household is negative and significant for both the years. Besides, access to electricity connection and sanitary latrine is found to be significantly associated with the food consumption score. This can be attributed to the fact that households who have access to sanitary latrine and electricity connection have better economic status and can therefore afford a better diet. The coefficients of land ownership and value of non-land asset also exhibit significant values. Last but not the least, the farming diversity index is strongly associated with food consumption which further corroborates the fact that agriculture plays a vital role in promoting the food consumption score.

5. Summary and Conclusions

This paper uses the household-level data on food acquisition and consumption collected by the Bangladesh Bureau of Statistics as part of its household income and expenditure surveys to estimate diet diversity and the intake of different macro- and micronutrients using AO's conversion table of food items to nutrients. The major objective was to run a model of drivers of diet diversity and food consumption score and test whether agriculture and agricultural diversification matter in promoting diet diversity and hence nutritional outcomes.

The results show that the diet diversity and food consumption score has improved considerably in Bangladesh during 2000-2010. The energy intake remained almost stagnant, but there has been significant improvement in the intake of protein, vitamin A, and iron. The intake of zinc has marginally declined. The decline in per capita rice consumption over the period has led to a reduction in calorie, protein and zinc, but increased intake of animal products has compensated for the decline in protein and iron. Vitamin A increased from growing consumption of vegetables.

A multivariate regression model was estimated to find the factors associated with diet diversity. The significant factors are found to be household income, land ownership, the level of education of the head and the spouse, the sex of the household head, and the level of infrastructure development as measured by access to electrification. Controlling the effect of these variables, the findings show that the household's engagement in agriculture and the diversity in agricultural production positively affect diet diversity. The paper therefore concludes that agriculture promotes diet diversity, food consumption score and the nutrition outcomes.

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Appendix 1: Consumption of major food categories in rural and urban areas, and the country as a whole

Food group	Rural areas		Urban areas		Bangladesh	
	2000	**2010**	**2000**	**2010**	**2000**	**2010**
Rice	475.1	442.1	378	361.4	443.8	413.1
Wheat	17.4	22.3	28.5	31.5	21	25.6
Cereals	497.3	477.2	418.4	407.7	471.8	452.2
Pulses and legumes	15.3	11.9	19.1	15.1	16.5	13
Fish	36.2	46.3	40.8	54.9	37.7	49.4
Meat & eggs	10.6	14.5	22.5	24.8	14.4	18.2
Orange/yellow vegetables and fruits	40.1	56.9	47.8	52	42.6	55.1
Green/leafy vegetables	20.9	39.1	25	37.9	22.2	38.7
Other vegetables and fruits	107.8	104.4	108.4	110.9	108	106.7
Tubers/roots	71.1	90.4	69.4	86.4	70.6	89
Milk and dairy foods	27.2	29.2	29.1	35.4	27.8	31.4
Oils and fats	11.9	19.7	19.6	25.8	14.4	21.9
Sweets	6.5	8.1	9.3	11.6	7.4	9.4

Note: Quantities measured in grams.

Appendix 2: Consumption of protein-enriched food items

Name of the food-item	Protein coefficient	Rural areas		Urban areas		Bangladesh	
		2000	**2010**	**2000**	**2010**	**2000**	**2010**
Bream (sea, dried)	39	1.1	1.2	1.0	0.7	1.1	1.0
Khesari dal	28	2.7	1.6	1.7	0.8	2.4	1.3
Lentils	28	5.2	5.1	12.1	10.2	7.4	6.9
Powdered milk (whole, cow)	27	0.1	0.2	1.1	0.8	0.4	0.4
Chicken	26	2.7	8.4	6.9	14.0	4.0	10.4
Green gram (split)	24	0.5	0.4	0.7	0.5	0.6	0.5
Black gram (split)	23	0.8	0.8	0.8	0.6	0.8	0.7
Duck	22	0.6	0.8	0.4	0.6	0.5	0.7
Goat	21	0.4	0.5	0.8	0.9	0.5	0.6
Beef	21	6.2	4.8	13.5	9.1	8.6	6.4

Note: Quantities measured in grams.

Appendix 3: Consumption of fat-enriched food items

Name of the food-item	Fat coefficient	Rural areas		Urban areas		Bangladesh	
		2000	2010	2000	2010	2000	2010
Ghee (vegetable)	100	0.0	0.0	0.1	0.0	0.0	0.0
Mustard oil	100	5.2	2.8	2.1	1.2	4.2	2.2
Soybean oil	100	6.7	16.9	17.5	24.5	10.1	19.6
Ghee (cow)	99.8	0.0	0.0	0.0	0.0	0.0	0.0
Powdered milk (whole, cow)	27	0.1	0.2	1.1	0.8	0.4	0.4
Cumin seed	18	0.7	0.9	1.0	1.2	0.8	1.0
Hilsa fish	17	2.8	2.0	5.4	5.9	3.7	3.4
Coriander seed	16	1.2	0.8	1.5	0.9	1.3	0.9
Duck egg	14	0.0	0.0	0.0	0.0	0.0	0.0
Mutton (lamb)	14	0.0	0.0	0.0	0.0	0.0	0.0

Note: Quantities measured in grams.

Appendix 4: Consumption of iron-enriched food items

Name of the food-item	Iron Coefficient	Rural areas		Urban areas		Bangladesh	
		2000	2010	2000	2010	2000	2010
Pickles	45	0.1	0.4	0.2	0.7	0.2	0.5
Cumin seed	45	0.7	0.9	1.0	1.2	0.8	1.0
Turmeric	19	2.6	2.7	3.1	2.6	2.8	2.7
Coriander seed	18	1.2	0.8	1.5	0.9	1.3	0.9
Bengal gram (split)	8.8	4.8	4.0	2.9	3.0	4.2	3.6
Green gram (split)	7.2	0.5	0.4	0.7	0.5	0.6	0.5
Betel leaves	7	3.6	3.9	2.6	2.8	3.2	3.5
Rice (flattened)	6.8	0.9	1.1	0.5	1.0	0.8	1.1
Khesari dal	5.3	2.7	1.6	1.7	0.8	2.4	1.3
Lentils	5.1	5.2	5.1	12.1	10.2	7.4	6.9

Note: Quantities measured in grams.

Appendix 5: Consumption of zinc-enriched food items

Name of the food-item	Zinc Coefficient	Rural areas		Urban areas		Bangladesh	
		2000	2010	2000	2010	2000	2010
Coriander seed	4.6	1.2	0.8	1.5	0.9	1.3	0.9
Goat	4.0	0.4	0.5	0.8	0.9	0.5	0.6
Mutton (lamb)	3.9	0.0	0.0	0.0	0.0	0.0	0.0
Cumin seed	3.9	0.7	0.9	1.0	1.2	0.8	1.0
Lentils	3.9	5.2	5.1	12.1	10.2	7.4	6.9
Powdered milk (whole, cow)	3.7	0.1	0.2	1.1	0.8	0.4	0.4
Beef	3.5	6.2	4.8	13.5	9.1	8.6	6.4
Khesari dal	3.4	2.7	1.6	1.7	0.8	2.4	1.3
Bengal gram (split)	3.3	4.8	4.0	2.9	3.0	4.2	3.6
Mola fish	3.2	4.3	4.6	4.2	4.0	4.3	4.4

Note: Quantities measured in grams.

Appendix 6: Consumption of vitamin A-enriched food items

Name of the food-item	Vitamin A	Rural areas		Urban areas		Bangladesh	
	Coefficient	2000	2010	2000	2010	2000	2010
Mola fish	2680	4.3	4.6	4.2	4.0	4.3	4.4
Chili, red (dry)	747	3.0	3.1	3.0	2.5	3.0	2.9
Ghee (cow)	642	0.0	0.0	0.0	0.0	0.0	0.0
Butter, salted	633	0.0	0.0	0.0	0.0	0.0	0.0
Spinach	409	20.9	39.1	25.0	37.9	22.2	38.7
Duck egg	362	0.0	0.0	0.0	0.0	0.0	0.0
Powdered milk (whole, cow)	238	0.1	0.2	1.1	0.8	0.4	0.4
Climbing fish (koi)	215	0.5	0.8	0.5	1.9	0.5	1.2
Palm (ripe)	208	0.3	0.3	0.1	0.3	0.3	0.3
Hen egg	165	0.0	0.1	0.1	0.2	0.1	0.1

Note: Quantities measured in grams.

Appendix 7: Expenditure of the major food categories as a share of annual food expenditure and annual total expenditure

Food group	Rural Areas				Urban Areas			
	Share of foodexpenditure		Share of total expenditure		Share of foodexpenditure		Share of totalexpenditure	
	Year 2000	Year 2010	Year 2000	Year 2010	Year 2000	Year 2010	Year 2000	Year 2010
Rice	42.3%	38.0%	22.6%	17.6%	30.0%	29.2%	12.6%	11.8%
Wheat	0.9%	2.9%	0.4%	1.3%	1.8%	3.7%	0.6%	1.4%
Cereals	43.1%	41.4%	23.0%	19.2%	31.8%	33.5%	13.3%	13.4%
Pulses and legumes	2.8%	2.1%	1.4%	0.9%	3.3%	2.7%	1.3%	1.0%
Meat and fish	5.7%	11.9%	2.8%	5.3%	7.6%	13.5%	2.7%	5.0%
Small fish	5.0%	4.6%	2.6%	2.0%	4.5%	5.1%	1.7%	1.9%
Eggs	1.3%	1.4%	0.6%	0.6%	1.9%	2.0%	0.7%	0.7%
Orange/yellow vegetables and fruits	2.6%	3.0%	1.3%	1.3%	3.5%	3.6%	1.2%	1.3%
Green/leafy vegetables	0.8%	1.1%	0.4%	0.5%	0.9%	1.0%	0.4%	0.4%
Other vegetables and fruits	5.8%	4.8%	3.0%	2.1%	5.9%	5.5%	2.3%	2.0%
Tubers/roots	3.8%	3.1%	2.0%	1.4%	3.4%	2.8%	1.4%	1.1%
Milk and dairy foods	2.5%	2.3%	1.2%	1.0%	3.1%	2.8%	1.0%	1.0%
Oils and fats	3.8%	4.5%	2.0%	2.1%	4.1%	4.8%	1.6%	1.8%
Sweets	3.6%	1.0%	1.8%	0.4%	6.3%	1.1%	2.3%	0.4%