Essays on food demand and supply in Bangladesh

by

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B.S., Bangladesh Agricultural University, Bangladesh, 2002
M.S., Bangladesh Agricultural University, Bangladesh, 2004

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

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Abstract

The socio-economic and demographic conditions of Bangladesh have changed dramatically during the last three decades after economic and political reforms in 1991, which lead to change in food preferences both in rural and urban areas. Following the global trend of increasing commodity prices, the price hike in Bangladesh has raised policy concerns regarding the potential shifts in consumption patterns and welfare loss. Furthermore, the agricultural industry and the food supply in Bangladesh is highly susceptible to the effects of climate change and increased frequency of extreme weather events. The accurate and timely insights on food demand patterns in Bangladesh under the changing socio-economic scenarios can have important implications for food and nutritional security, price stability, poverty alleviation and appropriate import-export policy of the country. Policies on these issues cannot produce desired outcome without accurate estimation of consumer demand. However, despite the increasing need for improved understanding of food demand in Bangladesh, the literature in this area is relatively limited.

The purpose of this dissertation is to provide insight on food demand and supply in Bangladesh by utilizing recent advancements in demand modeling and the latest and most complete data available on household food consumption in Bangladesh. The first essay examines welfare consequences of rising food prices in Bangladesh utilizing the Exact Affine Stone Index (EASI) demand model. Bangladeshi households experienced a sharp increase in food commodity prices during the last two decades especially in the period of 2007-2008. Inflation moved to two-digit level in 2007-08 and also in 2010-11 reaching 12.28% and 10.89% respectively, mostly driven by inflation in food prices. Estimating welfare impact of rising food price utilizing the prevalent demand models like the Almost Ideal Demand System (AIDS) and its' family models

may lead to biased estimate due to a number of practical limitations of these models. The EASI model has number of advantages over AIDS due to its flexibility in analysis of disaggregated consumer level data. In Essay 1, we utilize EASI model to estimate price and expenditure elasticities of 14 major food items using secondary data extracted from Household Income and Expenditure Survey (HIES) conducted by the Bangladesh Bureau of Statistics. The estimated elasticities are then used to evaluate the welfare consequences of rising food prices in Bangladesh. Welfare analysis based on both actual price change and simulated price change indicates that the welfare loss is the highest for lower income household. Further, the results indicate that the welfare loss of rural households was higher compared to that of urban households.

The focus of the Essay 2 is on the analysis of pre-commitments in food demand in Bangladesh. Pre-committed demand is the portion of demand where the quantity demanded is not sensitive to changes in price or income. In the presence of pre-commitments, the demand is almost perfectly inelastic over the pre-committed portion of demand leading to biased estimates if it is not accounted for in modeling. The phenomenon of pre-committed demand for food has been more commonly observed in developing countries. Similar demand patterns are likely in Bangladesh with high proportion of low-income households and strong dependence on a range of staple food items by Bangladeshi households. Thus, in Essay 2, we utilize the generalized EASI (GEASI) demand model to estimate the demand elasticities of 14 major food items in Bangladesh by accounting for potential pre-commitments. The evidence of pre-committed demand is found in case of rice, pulse, vegetables and onion which accounts for 16.20%, 32.04%, 9.73% and 21.82% respectively. The new insights generated by the analysis in Essay 2 have important policy implications and can inform policy initiatives related to social safety net programs and food security of low-income households in Bangladesh.

The Essay 3 focusses on forecasting supply and demand of rice in Bangladesh. Rice is not only the main staple food in Bangladesh but is also the single most important agricultural crop in terms of its contribution to national economy and its role in creating income and employment opportunities and ensuring food security. The analysis of rice supply and demand has always been at the center of policy makers attention in Bangladesh since the deficit tends to cause significant increase in price and resulting consumer welfare loss, while the surplus tends to result in price reductions negatively affecting farm profitability and household wellbeing in rural areas where the rice farming is the main source of income. Thus, the objective of this study is to forecast the supply and demand of rice with an aim to improve the understanding of potential deficit or surplus trends in the short- and long-term future. The analysis in Essay 3 utilizes ARIMA, Holt-Winter, and double exponential forecasting models. The findings reveal that both rice production and consumption will gradually increase in the short-run and in the long-run in Bangladesh. The forecasting results by ARIMA and Holt-Winter approaches show that there might be deficit in rice production in Bangladesh both in short-run and long-run with exceptions of rare surplus years. However, the results of double exponential approach indicate potential surplus in rice production both in the short-run and the long-run. Importantly, the deficits and surpluses are not large enough in magnitude to influence the price of the rice. The findings of the study would be useful for policy makers to formulate policies on rice production, distribution, export and import.

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Dedication

Dedicated to My

Most Reverend Parents

Whose Prayers and Sacrifices Lighted My Way

And

To My Beloved Wife and Children

Chapter 1 - Introduction

Bangladesh is a rapidly growing developing economy in South Asia. Since 1991, economic reforms in Bangladesh focusing on market liberalization and industrialization have significantly increased economic activities and per capita income. Per capita national income has risen from 759 US dollar in 2008-09 to 1610 US dollar in 2016-17, more than double within 8 years (BBS 2017a; BBS 2018). The urbanization process in Bangladesh is also mounting. In 2001, about 20% of the population lived in urban areas; this share increased to 35.04% by 2016 (World Bank 2017). Furthermore, the pressure of population growth is also intensifying. The population in Bangladesh is projected to grow to 178-230 million by 2050 from 160 million in 2016 (UN 2016). Changes in income, urbanization, demography and associated changes in lifestyles are driving changes in food demand and consumption patterns (Huang & Bouis 2001; Godfray et al. 2010; Regmi & Dyck 2001; Regmi et al. 2001; Zheng et al. 2015). Mottaleb et al. (2018) illustrated that Bangladesh, the traditional rice-consuming country is experiencing gradual reduction in rice consumption. Additionally, demand for higher value products such as meat, fish and egg is increasing (Mottaleb et al. 2018; BBS 2017b). Consequently, policy makers and global agro-food industry players have an increasing interest in understanding the complete food demand system of the consumer in Bangladesh. The accurate and timely insights on food demand patterns in Bangladesh under the changing socio-economic scenarios can have important implications for food and nutritional security, price stability, poverty alleviation and appropriate import-export policy of the country. Policies on these issues cannot produce desired outcome without accurate estimation of consumer demand. However, despite the increasing need for improved understanding of food demand in Bangladesh, the literature in this area is relatively limited.

Few studies on consumer food demand analysis in Bangladesh have been performed using traditional Almost Ideal Demand System (AIDS) and its family models. Although AIDS and its variant models have some advantages, they also have a number of notable limitations. The more recently introduced Exact Affine Stone Index (EASI) model developed by Lewbel and Pendakur (2009) has some distinct advantages over other traditional demand models in terms of modelling flexible Engle curves and allowing for unobserved consumer heterogeneity. Further, EASI is more refined model for welfare and policy analyses on disaggregated consumer level data (Zhen et al. 2013). Consequently, the objective of this dissertation is to analyze food demand in Bangladesh by utilizing the EASI approach and to evaluate welfare consequences of rising food price in Bangladesh. Further, this dissertation will also employ generalized EASI (GEASI) demand model to address pre-committed food demand in Bangladesh. Additionally, demand and supply of rice, the most important crop in Bangladesh will be analyzed utilizing different forecasting models to estimate the amount of deficit or surplus production in the country for both short-run (5 years) and long-run (35 years).

To achieve these objectives following three research essays have been developed:

Essay 1: Welfare Consequences of Rising Food Prices in Bangladesh: An Application of EASI Model.

Essay 2: Food Demand Estimation in Bangladesh Addressing Pre-Committed Demand.

Essay 3: Deficit or Surplus Rice Production in Bangladesh: Evidence from Rice Production and Consumption Forecast.

The rest of the dissertation is organized in four chapters, three of which correspond to Essays 1-3, and the final Chapter 5 provides an overall conclusion to the dissertation.

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Chapter 2 - Welfare Consequences of Rising Food Prices in Bangladesh: An Application of EASI Model

2.1 Problem Statement

The political and economic reforms in Bangladesh in the forms of strengthened democratic institutions and market liberalization in 1991 triggered the economic growth in the country. During the last decade, the annual growth rate of GDP was consistently over 6% in the country (BBS 2018) and particularly, the growth was over 8% during the financial year 2018-19 (BBS 2019). As a result, per capita income, industrialization and urbanization trends exhibited consistent growth, in turn affecting food demand and consumption patterns of the households both in rural and urban areas. Additionally, the global commodity price hike in 2007 had its impact on food prices in Bangladesh which raised concerns of policy makers and development organizations regarding the consumer welfare. The need for up-to-date analysis and insights on food supply and consumption patterns in Bangladesh is high among policy makers, NGOs and agribusiness market participants. This is especially true in light of recent socioeconomic and demographic changes and the growing need to ensure food and nutritional security and price stability.

Bangladesh is a rapidly growing developing economy in South Asia. Market oriented economic reform, increasing labor intensive industrialization like expansion of garments and textile industries, businesses and services, and rural-urban and overseas migration enhanced the economic growth in the country (Nargis and Hossain 2006). Per capita national income has risen from 759 US dollar in 2008-09 to 1610 US dollar in 2016-17, more than double within 8 years (BBS 2017a; BBS 2018). The urbanization process in Bangladesh is also mounting up. In 2001, about 20% of the population lived in urban areas; the share increased to 35.04% by 2016 (World

Bank 2017). Changes in income, urbanization, demographic shifts and associated changes in lifestyles lead to change in food demand and consumption patterns (Huang & Bouis 2001; Godfray et al. 2010; Regmi & Dyck 2001; Regmi et al. 2001; Zheng et al. 2015). Food preferences tend to shift from cereals toward higher value items such as fish, meat, dairy products, and fruits with increase in income (Gerbens-Leenes et al. 2010; Huang & David 1993; Ito and Grant 1987; Kearney 2010; Mittal 2007; Pingali 2006; Rao 2000). Rapid urbanization can also change dietary pattern at the household level. Urban households may consume more fat, protein and western-style foods due to lifestyle changes and increasing opportunity costs of preparing food in house by especially female members (Huang & David 1993; Regmi & Dyck 2001). According to HIES 2016, per capita rice intake was decreased from 439.64 gm per day in 2005 to 367.19 gm per day in 2016. Mottaleb et al. (2018) also found that Bangladesh, the traditional rice-consuming country is experiencing gradual decline in rice consumption. Demand for higher value products such as meat, fish and egg is also increasing (Mottaleb et al. 2018; BBS 2017b).

The sharp increase in global food commodity prices during the past decade have raised concern about decline in economic welfare and rise in poverty throughout the world especially in developing countries. This motivated researchers and policy makers to focus on consumer welfare analysis to formulate appropriate policies on food security and poverty issues (Attanasio et al. 2013). Following the global trend of increasing food price, Bangladesh had also experienced a significant price hike in food commodities, especially in case of rice during the last decade. The national wholesale price of rice increased from Taka 15.9 per kg in January 2006 to Taka 30.8 per kg in August 2008, over 94% increase during this period (Sulaiman et al. 2009). Inflation moved to two-digit level in 2007-08 and 2010-11 calculated as 12.28% and 10.89% respectively, mostly led by food inflation (Hossain et al. 2013). Higher rice prices can likely affect household welfare since rice is a staple food in Bangladesh and constituted 62% budget share of total food expenditure of the poorest people in 2008 (Sulaiman et al. 2009). While exploring consumer food demand structure is vital to measure poverty and welfare impact due to change in price and income, very limited number of studies have been conducted in this area in Bangladesh.

Several studies (Vu and Glewwee 2011; Attanasio et al. 2013; Ferreira et al. 2013) estimated the household welfare loss in different countries due to food price change that spiked in 2008 and later and found heterogeneous impacts. Vu and Glewwee (2011) calculated the impacts of raising food prices on welfare in Vietnam and the result indicated that higher food prices raised the average Vietnamese household's welfare because the average welfare loss of households whose welfare declined (net purchaser) was smaller than the average welfare gains of those whose welfare increased (net seller). On the contrary, Attanasio et al. (2013) found that the poor have been affected by the recent increases and changes in relative prices of food in Mexico. In case of Brazil, Ferreira et al. (2013) showed that lower income group were comparatively less affected than middle income group. The heterogeneity in findings might be due to differences in household characteristics, macro-economic variables and also models used for demand estimation. For example, Hovhannisyan and Shanoyan (2018) found differential effects on welfare consequences of raising food prices in urban China from Exact Affine Stone Index (EASI) and Quadratic Almost Ideal Demand (QUAIDS) model estimates, which highlights the bias in elasticity estimates. Therefore, studies with application of advanced demand models are essential to capture the exact impact of food price increase on welfare and poverty through estimating unbiased own and cross price elasticities.

Several alternative empirical models have been discussed in the literature for the estimation of a food demand system. Among those models, AIDS model of Deaton and Muellbauer (1980) and its family models have been popular and widely used due to being consistence with theory and simplicity in estimation procedures. However, these models subject to Gorman's (1981) rank restriction and cannot recognize unobserved consumer heterogeneity. The Exact Affine Stone Index (EASI) developed by Lewbel and Pendakur (2009) is superior to AIDS and its variant in the sense that EASI demand specification relieves Gorman's (1981) rank restriction on Engle curves. Moreover, EASI error terms can be interpreted as random utility parameters that represent unobserved heterogeneity of preferences (Lewbel and Pendakur 2009). Further, EASI is more refined model for welfare and policy analyses on disaggregated consumer level data (Zhen et al. 2013).

Finally, assessing the impact of price hike on welfare is not easy due to substitution effects and household heterogeneity (Attanasio et al. 2013). Household may have been able to substitute food commodities to limit the impact of food price rise on their welfare. Furthermore, most of the poor household in Bangladesh live in rural areas and they are also food producers, not just consumers (World Bank 2017). Therefore, food price rise might cause an increase in welfare for some poor households. To evaluate the impacts of raising food prices on poverty and welfare, the need of advanced demand model is essential to capture household heterogeneity and substitution effects which can be better modelled by the EASI demand system. Thus, this study employs the EASI model to estimate household demand elasticities and welfare impact of rising food price in Bangladesh. Importantly, this is the first application of recently developed EASI demand model in demand analysis in Bangladesh.

2.2 Objectives of the Study

The general objective of the study is to gain insight on food demand patterns in Bangladesh. However, the specific objectives are:

i) to estimate consumers' food demand structure using EASI approach.

ii) to analyze the impact of rising food price on welfare of Bangladeshi households.

2.3 Literature Review

2.3.1 Food demand estimation using EASI approach

Magana-Lemus et al. (2013) examined the impacts of rising food prices on poverty and welfare of Mexican households employing an approximate/linearized version of the Exact Affine Stone Index (EASI) demand system. The study finds the evidence of non-linearity in case of Engle curves for most commodity groups, which justifies the use of EASI model. Due to increase in prices of five food groups from 2006 to 2010, an additional 514,000 households fell below the food poverty level.

Li et al. (2015) applied EASI model to analyze Chinese household consumer demand in urban area. The findings of the study support a demand system rank that is more than three to five. The results indicate that heterogeneity in demographic characteristics and price affect Chinese household consumer demand. More specifically, demographic characteristics like gender, the education level of householder, marital status, the number of minor children, the number of adult and migration would affect household demand structure.

Zhen et al. (2013) used an approximate Exact Affine Stone Index (EASI) incomplete demand system to predict the effect of sugar-sweetened beverage (SSB) taxes on demand for 23 categories of packaged foods and beverages. This study advocates to use of incomplete demand model in applicable cases instead of conditional demand model to get unbiased estimates of welfare. A conditional model cannot capture substitutions among SSBs and other foods and provides biased estimates of the potential positive nutritional effect of increasing SSB prices. However, the incomplete demand model alone cannot predict household compensation for reduced SSB consumption without a price endogeneity correction. An increase in the price of SSBs of one half-cent per ounce leads to decrease calorie intake by 13.2 kcal for the low-income population and 6.5 kcal for the high-income population from the 23 foods and beverages but increase sodium and fat intakes as a result of product substitution.

Ogura (2016) estimated the cost-of-living index to quantify the impact of price changes on Japanese households using EASI model. This study used household survey data by Japanese Statistics Bureau from 1989 to 2011 for food and non-food items. Due to substitution effect, the cost-of-living index was shifted upward indicating an increase in consumer surplus.

Hovhannisyan and Shanoyan (2018) utilized EASI model to estimate welfare consequences of rising food prices in urban China using nationally representative provincial-level panel data. This study extended EASI model to fixed-effects EASI (FE-EASI) model to capture provincial-level unobserved consumer preference heterogeneity. Consumer welfare loss relative to consumer food expenditures was moderate despite rise in food commodity prices. Further, the study compared the performance between EASI and Quadratic AIDS (QAIDS) and proved the superiority of EASI model over QAIDS model.

2.3.2 Food demand estimation in Bangladesh

Several attempts have been made to estimate food demand in Bangladesh. In earlier studies (Alamgir and Berlage 1973; Mahmud 1979), the estimation of food demand focused only on food grains, especially rice and wheat using regression models like semi-log and/or inverse types. Subsequently in the 1980s and later, a larger basket of food items including all important household items like rice, wheat, pulses, fruits and vegetables, fish, meat, egg, milk, edible oils, spices etc. was incorporated in the demand system mostly utilizing the AIDS model (Chowdhury 1982; Ahmed and Shams 1994; Shahabuddin and Zohir 1995; Goletti 1993; Mullah 2005; Murshid et al. 2007; Huq and Arshad 2010; Ganesh-Kumar et al. 2012). Several studies concentrated on estimating demand for specific food items like fish (Ali 2002), meat (Wadud 2006), dairy products (Hannan et al. 2010) and potato (Sabur 1983; Huq et al. 2004). Most of the studies used data from different periods of household income and expenditure survey (HIES) conducted by Bangladesh Bureau of Statistics (BBS). To author's best knowledge there haven't been any studies utilizing advanced EASI model in estimating consumer demand.

In previous demand studies in Bangladesh, Chowdhury (1982) applied the Frisch (1959) method for estimating elasticities of demand under condition of want independence with methodological advantage of it over little availability of price data. In contrary, Bouis (1989) estimated food demand elasticities of Bangladesh using 1973/74 Household Expenditure Survey data assuming marginal utility of consumption of any food depends on the level of consumption of all other foods. Pitt (1983) and Goletti (1993) used Tobit method to estimate the food demand system in Bangladesh. On the other hand, Ahmed and Shams (1994) calculated consumers demand using almost ideal demand system (AIDS) based on household consumption and nutrition survey data conducted by the International Food Policy Research Institute (IFPRI) over the period from

September 1991 to November 1992 in Bangladesh. Furthermore, Mullah (2005) studied consumer demand behavior in Bangladesh by using the AIDS model for the HIES 2000 data. He estimated the expenditure elasticity for different food and non-food items. More recently, Huq and Arshad (2010) estimated price and income elasticity of demand for different food items in Bangladesh employing the linear approximate AIDS (LA-AIDS) model with a corrected Stone price index using HIES data during the years 1983/84, 1988/89, 1991/92, 1995/96, 2000, and 2005/06. The most recent attempt to study demand elasticities for food items in Bangladesh was made by Ganesh-Kumar et al. 2012. In this study, household direct demand for 13 food items has been modeled using the quadratic almost ideal demand system (QAIDS) specification, whose parameters are estimated using the Household Income and Expenditure Survey, 2005.

In case of other consumers food demand related studies in Bangladesh, Shahabuddin (1989) analyzed the changing pattern of food consumption using the Household Expenditure Survey data from 1973/74, 1976/77, 1981/82 and 1983/84 rounds. Over the study period from 1973/74 to 1983/84, although per capita real expenditure on food increased by 22% in rural areas, it was unchanged in urban areas. Per capita food grain consumption increased in rural areas by 11.9% due to the net result of an increase in rice consumption by about 20% and a decrease in wheat consumption by about 25%. On the other hand, per capita food grain consumption in urban areas decreased by 2.4% because of the net result of an increase in rice consumption by about 24% and a decrease in wheat consumption by about 52% over the period.

Talukder (1990) estimated food consumption parameters for six selected food items-rice, wheat, potatoes, pulses, fish and edible oil in Bangladesh using Household Expenditure Survey data in the year 1981/82. In comparison between rural and urban areas for rice and wheat, the estimates revealed that while the absolute value of the own-price elasticity for rice of the rural households was twice that of the urban households, the absolute value of that for wheat of the urban households was more than four times that of the rural households.

Ahmed (1993) attempted to provide an understanding of the food consumption and nutritional patterns in rural Bangladesh. The analyses are based on primary data from rural household survey on consumption and nutrition, conducted by IFPRI in 1991/92. The findings of the study suggest that rural households, particularly, the poor are highly responsive to changes in income in adjusting their food consumption patterns. The food consumption patterns across income groups show that the consumption of wheat declines as incomes rise, suggesting wheat is an inferior commodity in rural Bangladesh. In contrast, rice consumption increases sharply with income. The findings show a high degree of regional and seasonal variations in food consumption and nutritional status. Expenditure on rice accounts for a large budget share of the poor families. Because of this, a falling rice price significantly increases real income, and consequently, improve food consumption and nutritional status of the poor.

Halder et al. (2003) explored the patterns and trends in food consumption in poor urban and rural households in Bangladesh. There were important changes occurring in Bangladesh during the 1990s that drove changes in food consumption patterns and the food system. The study shows that demand for higher value products such as livestock products, fruits and vegetables has increased as a result of higher disposable income. Increasing urbanization and industrialization is leading to increase in income. Industrial workers may also change the nature of their consumption patterns, consuming less food at home and more from food outlets close to, or on the journey to, work. These adaptations may affect the type and level of processing of food items consumed.

Ghosh (2010) analyzed rural-urban consumption patterns in Bangladesh using secondary data from 1973 to 2005. In Bangladesh, the income, expenditure and consumption expenditure per household have been increased gradually over the study periods. The study finds a rising trends of income, expenditure and consumption expenditure in both rural and urban areas but at the same time consumption disparities between the rural and urban areas are increasing. In both rural and urban areas, cereals, vegetables, edible oil and clothing are considered as necessities while, pulses and beverages are treated as necessities in urban areas. In contrary, egg, fish, meat and sugar are found to be luxuries in both urban and rural areas in the recent years. Differences are found in the consumption patterns in both rural and urban areas which may be caused by factors like income, demographic and various social elements.

Sadika et al. (2013) studied the food consumption pattern of rural and urban areas of Bangladesh to make a comparison of calorie and protein intake between 2005 and 2010. The study used Household Income and Expenditure survey data from 2005 and 2010 rounds. In 2010, the average per capita per day calorie intake was 2344.6 kcal in rural areas compared to 2244.5 kcal in urban areas while, the average per capita per day protein intake was 65.24 gm in rural areas and it was 69.11 gm in urban areas. The study shows that average calorie and protein intake had a gradual increasing trend over the years in rural and urban areas due to the growing awareness of people about health.

Mottaleb et al. (2018) examined the changing food consumption of households in Bangladesh. Using information from more than 29,000 households, the study demonstrates that, with the increase in income and urbanization, this traditional rice-consuming country is increasingly consuming more wheat and less rice. Households are also consuming more fish, vegetables and pulses over time. The changes in the relative consumption in Bangladesh are prominent both in rural and urban areas. This study econometrically demonstrates that, in general, education, income and urbanization are the major driving forces behind the changing cereal and food consumption in Bangladesh. Still, rich households consume more food items, including rice, than the poor households. Based on the findings, this study warns that with an increase in income, population and rapid urbanization, developing countries including Bangladesh, not only need to supply more food items than before, but particular attention should also be given to the changing food basket—i.e., the enhanced consumption of food items, such as wheat, fish and pulses.

2.3.3 Impact of price hike in Bangladesh and other developing countries

Nargis and Hossain (2006) related the dynamics of rural poverty reduction to the structural shift in income generation mechanism from farm to nonfarm activities, changing household factor endowments, and the adoption of improved agricultural technologies over time. This study used data from a nationally representative longitudinal survey of rural households in Bangladesh conducted in three waves in 1988, 2000, and 2004. The findings show that the occupational shift from the farm to the nonfarm sector, such as trade, business, and services, as well as the expansion of cultivated areas through tenancy, enhance income growth. Geographic mobility, overseas migration in particular, makes a significant contribution to income growth as well. The reduction in poverty appears to be vitally dependent on the enhancement of the endowment of human and physical capital that augments the poor households' capability to better exploit income-generating opportunities and place the households on a sustainable route out of poverty.

Balagtas et al. (2014) assessed the effects of the dramatic rise in agricultural commodity prices during 2007–2008 on income dynamics and poverty among rural households in Bangladesh using data set from a nationally representative longitudinal survey of rural households in Bangladesh collected in four waves in 1988, 2000, 2004, and 2008. They find that the price of a balanced food basket increased by more than 50% during 2000–2008, while household income rose only 15%. As a result, the incidence and severity of rural poverty in Bangladesh sunk to pre-2000 levels during 2004–2008. Thus, the price spikes in 2007–2008 helped push an additional 13 million people into poverty in rural Bangladesh. Moreover, the study finds that the determinants of poverty have not been time invariant. In particular, agricultural production, which had previously been associated with a higher incidence of poverty, served as a hedge against higher food prices during 2004–2008.

Hasan (2016) studied the impact of the rice price increase between 2005 and 2010 on consumption in rural Bangladesh. Using the Household Income and Expenditure Survey (HIES) data, the study compares net rice buyers and sellers to self-sufficient households. To identify the effect of rice price changes on household consumption of rice, non-rice food and nonfood items, difference-in-differences (DiD) technique was employed. Findings indicate that the surge in domestic rice prices between 2005 and 2010 reduced the non-rice food consumption of net rice buyer households by 7%, compared to the households who are self-sufficient in rice production. However, it did neither affect their rice nor their nonfood consumption. In contrast, while no significant effect of rice price increases on the rice consumption of net rice sellers was found, a 9% increase in their non-rice food consumption was observed. The inelastic demand for rice of both buyers and sellers indicates a quadratic Engel curve for rice in rural Bangladesh as found in earlier studies on developing countries.

Mishra et al. (2015) examined the effects of off-farm income on food expenditures of rural Bangladeshi households. Data for this study were taken from Bangladesh's Household Income and Expenditure Survey (HIES) carried out in 2000, 2005, and 2010. The findings suggest that the impacts of off-farm income are uniformly positive across the unconditional quantile regression and significantly increase food consumption expenditures for all quantiles, except for the 25th quantile. Most importantly, this article argues that female-headed rural households in which the female works off the farm tend to have significantly lower food expenditures. A strong nonfarm sector has provided opportunities for farming households to diversify their income sources and increase their food consumption expenditures.

Mghenyi et al. (2011) estimated the effects of a large increase (25%) in maize price on household welfare and poverty using first and second-order Taylor approximation as well as a semi-parametric method nested on Speckman estimator for a sample of rural Kenyan households. The authors used a nationwide cross-sectional survey data of 2004 concentrated mainly on smallholder farm households, conducted by the Tegemeo Institute of Egerton University and Michigan State University. The authors show that a 25% arbitrary increase in maize price leads to the welfare effects ranging from -10% (loss) to 10% (gain). Producers of maize gain and consumers lose form this increase in price. On the impact on poverty, Mghenyi et al (2011) find that a number of households from net buyer group move down below poverty line and a number of households from net sellers move up. Overall, they find that the effects price of increase on poverty are not much stronger regardless of whichever poverty line is used.

Minot and Dewina (2015) examined the effects of 2007-08 maize price increase on welfare and poverty for Ghanaian households using modified method of Deaton (1989) approach. They used 2005-2006 Ghana Living Standards Survey (GLSS). They find that in the short run net buyers of maize suffer from welfare loss as maize price rises and the welfare loss is highest for poorest quintile. For poverty, they show that under proportional marketing margin. The incidence of poverty rises by 0.3 percentage point in the short run and in the long run, change in poverty is 0. Under Fixed marketing margin, the incidence of poverty falls by 0.9 (1.5) percentage point in the short (long) run. They conclude that under different marketing margins, the impact of maize price increase on poverty is different and create different implications for the different household group.

Levin and Vimefall (2015) extended the study of Mghenyi et al. (2011)'s analysis by accounting for heterogeneous maize price increase. They assumed consumers and producers face separate price changes and estimate the welfare effect of that changes. To carry on the analysis, they used 2005-06 Kenya Integrated Household Budget Survey (KIHBS). Their results show that welfare of net sellers and buyers' changes by 14% and -11%, respectively. The poverty rate increases by 1-3 percentage points (PP).

Badolo and Traore (2015) conducted a similar study in Burkina Faso in the context of global price rise, as they examined rice price hike on poverty and income inequality. In order to calculate the effect of rice price increase on real income, they used the concept of compensating variation (CV), originally developed by Deaton and Muellbaur (1980). They used a cross-sectional named Living Standard Survey, conducted over the period 2002-2003. They find that households lose as rice price goes up and the loss of the households is more severe for dwellers in urban areas (-5.7% as compared to -2.2% for rural). Poverty rate rises in short run but mitigates in the long run. Poverty shows an upward trend ranging from 2.2-2.6 pp in the short run. They also find that higher price increases inequality.

2.4 Methods

2.4.1 Two- step estimation procedure for a censored EASI demand model

The EASI model is one of the most significant recent advancements in the toolbox of demand system estimation. The EASI model not only shares all of the desirable properties of the AIDS model but also provides additional benefits. First, it is not subject to the rank three limitation of Gorman (1981) and allows the Engel curves to take arbitrary shapes (Lewbel and Pendakur 2009). Second, the EASI error term can be interpreted as unobserved consumer heterogeneity, while the AIDS residual does not have this interpretation. This is important for welfare studies that use consumer-level data because much of the demand variation cannot be explained by observed consumer demographics and price changes and is left in the error term.

This study follows the approach in Hovhannisyan and Shanoyan (2018) to apply the EASI demand specification as follows:

$$w_{hit} = \sum_{j=1}^{N} \alpha_{ij} \, lnp_{hjt} + \sum_{l=1}^{L} \beta_{il} \, y_{ht}^{l} + \sum_{k=1}^{K} \gamma_{ik} \, z_{hkt} + u_{hit} \qquad (1)$$

$\forall \; h = 1, \dots .. H; i = 1, \dots .. N; t = 1, \dots ..$

where w_{hit} is the budget share of commodity i for household h in year *t*; *N* is the number of commodities analyzed and *H* is the number of regions; p_{hjt} denotes the price of commodity *j* in year *t*; y_{ht} is household real food expenditures in year *t*; *L* is the highest order of polynomial in real expenditures; *K* is the number of the exogenous demand shifters; z_{hkt} is the *k*th demand shifter; u_{hit} represents unobserved expenditure share determinants; and $\alpha_{ij}, \beta_{il}, \gamma_{ik}$ are parameters.

However, an important econometric issue arises as we are dealing with lot of zero consumption in our data set. Since data were collected during two-week period, there were many households who did not consume some food items during those periods, but this does not necessarily mean that they were not consuming those food items. Demand estimation by traditional EASI model without addressing the demand censoring will result in biased and inconsistent estimates of economic effect. Thus, we adopted two-step estimation procedure of Shonkwiler and Yen (1999) described as below:

Consider the following system of demand equations with limited dependent variables or left-censored variables:

$$w_{iht}^{*} = f(x_{iht}, \delta_i) + \varepsilon_{iht}\ , \qquad q_{iht}^{*} = z_{iht}'\theta_i + \nu_{iht} \qquad (2)$$

$$q_{iht} = \begin{cases} 1\ if\ q_{iht}^{*} > 0 \\ 0\ if\ q_{iht}^{*} \leq 0 \end{cases} \qquad w_{iht} = q_{iht} w_{iht}^{*}$$

(i = 1,2,…..,N ; h = 1,2,…..,H ; t = 1,2,…., T)

Where,

w_{iht} and q_{iht} are observed budget share and consumption of commodity *i* for household *h* in year *t* respectively,

w_{iht}^{*} and q_{iht}^{*} are corresponding latent variables,

x_{iht} and z_{iht} are vectors of exogenous variables,

δ_i and θ_i are vectors of parameters and,

ε_{iht} and ν_{iht} are random errors.

Assume $[\varepsilon_{iht}, \nu_{iht}]'$ is distributed as bivariate normal with cov $(\varepsilon_{iht}, \nu_{iht}) = \partial_i$ for each *i*. Then, the conditional mean of w_{iht} takes the following functional form:

$$E(w_{iht}/x_{iht}\ , z_{iht}; \nu_{iht} > -\ z'_{iht}\theta_i) = \mathfrak{f}\,(x_{iht}, \delta_i) + \ \partial_i \frac{\emptyset(z'_{iht}\theta_i)}{\Psi(z'_{iht}\theta_i)} \quad (3)$$

Since $(w_{iht}/x_{iht}\ , z_{iht}; \nu_{iht} \leq -\ z'_{iht}\theta_i) = 0$, given that w_{iht} is censored, the unconditional mean of w_{iht} is

$$E(w_{iht}/x_{iht}\ , z_{iht}) = \Psi(z'_{iht}\theta_{iht})\,\mathfrak{f}\,(x_{iht}, \delta_i) + \partial_{iht}\emptyset(z'_{iht}\theta_i) \quad (4)$$

Based on equation (4) for each *i*, the system of equation (2) can be written as

$$w_{iht} = \Psi(z'_{iht}\theta_i)\,\mathfrak{f}\,(x_{iht}, \delta_i) + \partial_i\emptyset(z'_{iht}\theta_i) + \xi_{iht} \quad (5)$$

Replacing $\mathfrak{f}\,(x_{iht}, \delta_{iht})$ with EASI specification we derived the following censored EASI demand model for analysis:

$$w_{iht} = \Psi(z'_{iht}\theta_i)\ (\textstyle\sum_{i=1}^{N} \alpha_i\, lnp_{iht} + \ \sum_{l=1}^{L} \beta_{il}\, y_{ht}^{l} + \sum_{k=1}^{K} \gamma_{ik}\, z_{hkt}) + \partial_i\emptyset(z'_{iht}\theta_i) + \xi_{iht} \quad (6)$$

Where, p_{iht} denotes the price of commodity *i* for household *h* in year *t*; y_{ht} is household real food expenditures in year *t*; *L* is the highest order of polynomial in real expenditures; *K* is the number of the exogenous demand shifters; z_{hkt} is the *k*th demand shifter; and $\alpha_i, \beta_{il}, \gamma_{ik}$ are parameters.

To simplify analyses, we employ an approximate EASI model provided by Lewbel and Pendakur (2009). Specifically, y_{ht} is represented as Stone price-deflated real expenditures provided below:

$$y_{ht} = lnx_{ht} - \sum_{i=1}^{N} w_{iht}\, lnp_{iht} \qquad (7)$$

Following Shonkwiler and Yen (1999), the equation (6) is estimated by a two-step procedure: i) estimation of θ_i using the binary outcome $q_{iht} = 1$ and $q_{iht} = 0$ through ML probit model, where q_{iht} is regressed on indicator variables like household head's age, gender, income, education, year, religion, region, and division ii) estimation of $\Psi\left(z'_{iht}\widehat{\theta_i}\right)$ and $\emptyset(z'_{iht}\widehat{\theta_i})$ based on $\widehat{\theta_i}$ and also the equation (6).

2.4.2 Welfare analysis

Consumer welfare impact of food price change is assessed via the Hicksian compensating variation (CV), given that the latter remains the most widely used welfare analysis tool. Let $E(p, u)$ denotes the minimum expenditure necessary to obtain utility u at a given price vector p with p_0 and p_1 representing original and new price vectors, respectively, and u_0 denote utility from food consumption. The CV estimate reflects the adjustment in consumer income needed to leave the consumer unaffected by a price change and is measured as follows:

$$(3) \qquad CV = E(p_1, u_0) - E(p_0, u_0) = p_1 q^h(p_1, u_0) - p_0 q_0(p_0, u_0)$$

Where, $q^h(p_1, u_0)$ is the compensated (Hicksian) demand, evaluated at a price vector p_1 and initial utility level u_0. A positive CV value implies welfare loss, as the initial utility level can only be obtained at a higher cost, while a negative CV indicates welfare gain.

To develop an empirically tractable version of equation (3), we revise it based on a vector of compensated quantity changes $dq^h = q^h(p_1, u_0) - q_0(p_0, u_0)$ as shown below:

$$(4) \qquad CV = p_1 dq^h + dp\, q_0(p_0, u_0)$$

Where, $dp = p_1 - p_0$ is a vector of price changes, and dq^h is calculated by the following equation:

$$(5) \qquad \frac{dq^h}{q} = \sum e^H \left(\frac{dp}{p}\right)$$

where e^H represents the compensated (Hicksian) elasticity

2.5 Data

2.5.1 Data source

The source of data for this study is Bangladesh Bureau of Statistics (BBS), the centralized official bureau under the ministry of planning in Bangladesh for assembling statistics on demographics, agriculture, the economy, and other facts about the country and disseminating the information. BBS has been conducting the Household Income and Expenditure Survey (HIES) on a regular basis as the core survey to provide with very important data like income, expenditure, consumption and poverty situation both in rural and urban areas representing the whole country. After the independence in 1971, BBS has successfully completed 16 rounds of HIES: 1973-74, 1974-75, 1975-76, 1976-77, 1977-78, 1978-79, 1981-82, 1983-84, 1985-86, 1988-89, 1991-92, 1995-96, 2000, 2005, 2010 and 2016. The present demand analysis is based on secondary data extracted from Household Income and Expenditure Survey (HIES) during the years 2000, 2005, 2010, and 2016. The reason behind choosing the last 4 round HIES data from 2000 to 2016 is that the scope of the survey was broadened in the year 2000 and accordingly it was renamed as Household Income and Expenditure Survey (HIES) which was named as Household Expenditure Survey (HES) in first 12 rounds survey after the independence. Moreover, the socio-economic characteristics as well as consumption pattern of the household changing with time that can be tractable with the most recent data set.

2.5.2 Data description

HIES covers wide range of socio-economic information at the household level on following 9 modules: i) Household information, ii) Education, iii) Health, iv) Economic activities and wage employment, v) Non-agricultural enterprises, vi) Housing, vii) Agricultural enterprises, viii) Other income and assets, and ix) Consumption. The HIES 2000, 2005, 2010, and 2016 data on household-level consumption is quite detailed. The consumption of food items in quantity and expenditure was divided into 17 major food categories and collected all consumption information for two-week period. The major categories were cereals, pulses, fish, eggs, meat, vegetables, milk and dairy products, sweets, oil and fats, fruits, drinks, sugar and molasses, tobacco and related items, spices, betel leaves, and betel nuts. In the cereal category, there were sub-categories of rice, wheat, and processed rice and wheat products. Again, rice was sub-categorized according to fine rice, medium rice, coarse rice, beaten flat rice, and popped (puffed) rice. Rice is a staple food in Bangladesh where per capita consumption is 367.19 gm per day which is the highest in the world (BBS 2017b). Rice constitutes 62% budget share of total food expenditure of the poorest people in Bangladesh (Sulaiman et al. 2009). Besides rice, egg, vegetables and oil are the most important food items in the basket of both poor and rich households for which a significant portion of pre-committed demand is expected to be present.

2.5.3 Sample size

The sample size in HIES 2000, 2005, 2010, and 2016 were 7440, 10,080, 12240, and 46080, respectively. Although the total number of households included in the last four round HIES survey was 75840, we dropped 14458 observation due to have extreme lower or higher values which were not sensible in the context of Bangladesh and finally, we have 61382 observation for analysis.

2.5.4 Data summary

This study confines the analysis to estimate the demand structure for 14 major food items that are most commonly consumed by the households of Bangladesh. The descriptive statistics presented in Table 2.1 show that meat is the most expensive food group in Bangladesh compare to other food groups. However, the price of mutton is the highest (271.28 Tk. /kg), followed by beef (205.22 Tk. /kg) and chicken (125.01 Tk. /kg). Conversely, the prices of egg (5.35 Tk. /kg) and vegetables (13.62 Tk. /kg) appear to be cheaper than other food commodity and thus remain popular among most of the household especially among lower income households. It is notable from Table 2.1 and also Figure 2.1 that the prices of all food items are continuously increasing over the years but there was a sharp increase in price of most of the commodities from 2005 to 2010 following the global trend of food price increase during the period. More specifically, the price of mutton and beef increased remarkably after 2005.

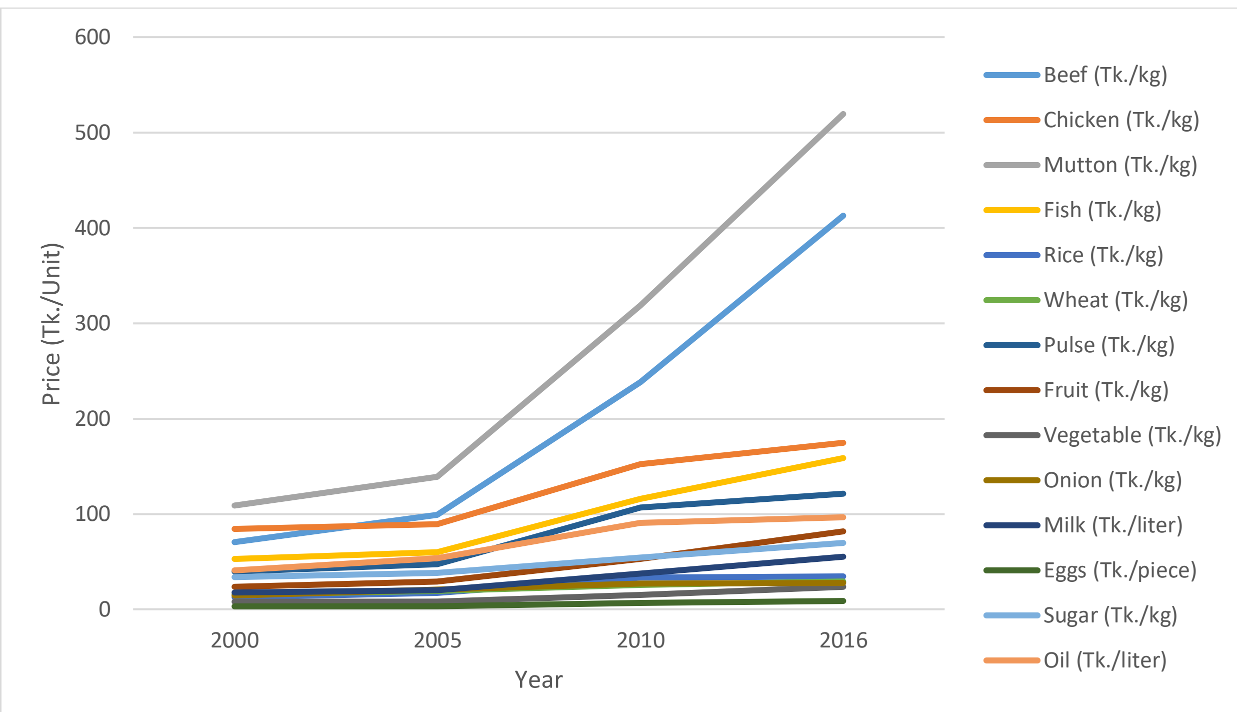

Figure 2.1 Time series plot of different food commodity prices from 2000 to 2016

Table 2.1 also summarizes per capita annual food consumption. Being a staple food, the per capita annual consumption of rice is very high (164.92 kg) compare to wheat consumption (6.12 kg) in Bangladesh. Nevertheless, the consumption of rice is gradually decreasing over the years due to change in food preferences and also health consciousness (Figure 2.2). Vegetable is another important food item for Bangladeshi people for having the largest per capita annual consumption (97.10 kg) after rice. Besides, fish and egg are frequently consumed and more popular food items than meat in Bangladesh. The reason behind that might be the increasing trend of commercial fish and poultry farming in Bangladesh which causes higher production and lower prices compare to meat categories. As it appears, the consumption of chicken, fish, onion, eggs and oil steadily increases from 2000 to 2016, while the consumption of other foods do not follow any regular pattern.

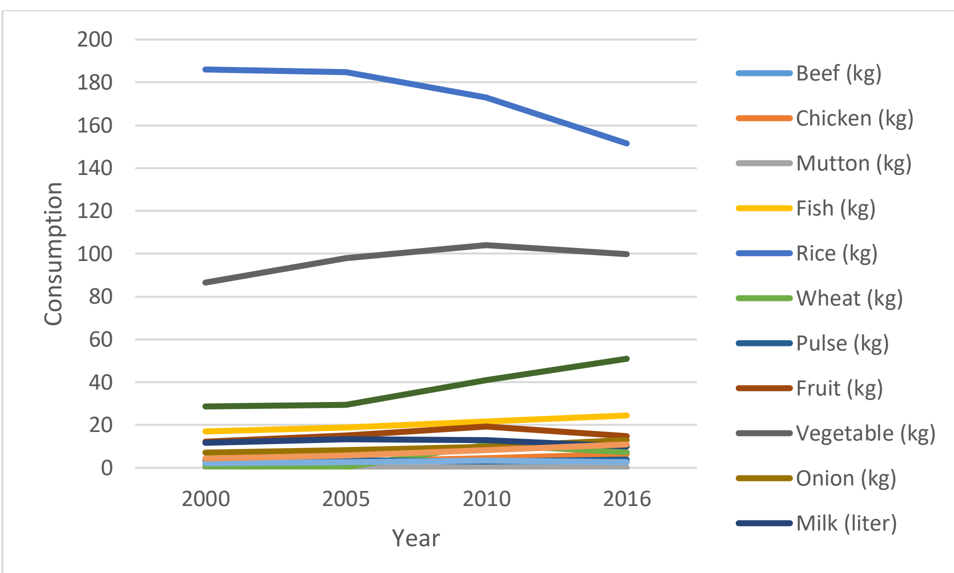

Figure 2.2 Time series plot of per capita annual food consumption from 2000 to 2016

It is also evident from the Table 2.1 and Figure 2.3 that the household spend most of the food budget to purchase rice (27.98%), followed by fish (13.54%), vegetables (9.14%), oil (3.84%) and beef (3.07%).

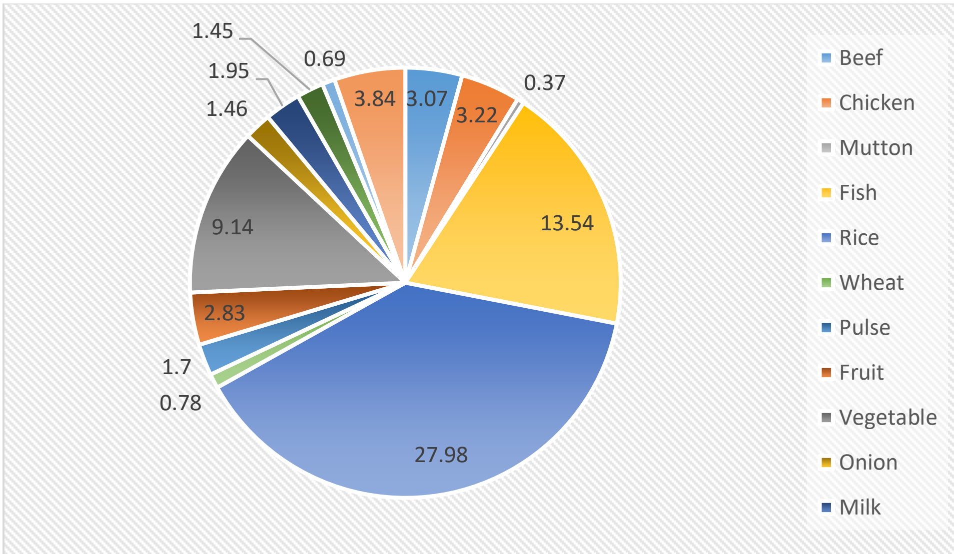

Figure 2.3 Budget shares of different food commodities in Bangladesh

Figure 2.4 shows that the per capita annual income is rising throughout the year from 17784 Tk. in 2000 to 57133 Tk. in 2016. However, the income rose remarkably from 2005 to 2010, became almost double due to expansion of economic activities in Bangladesh.

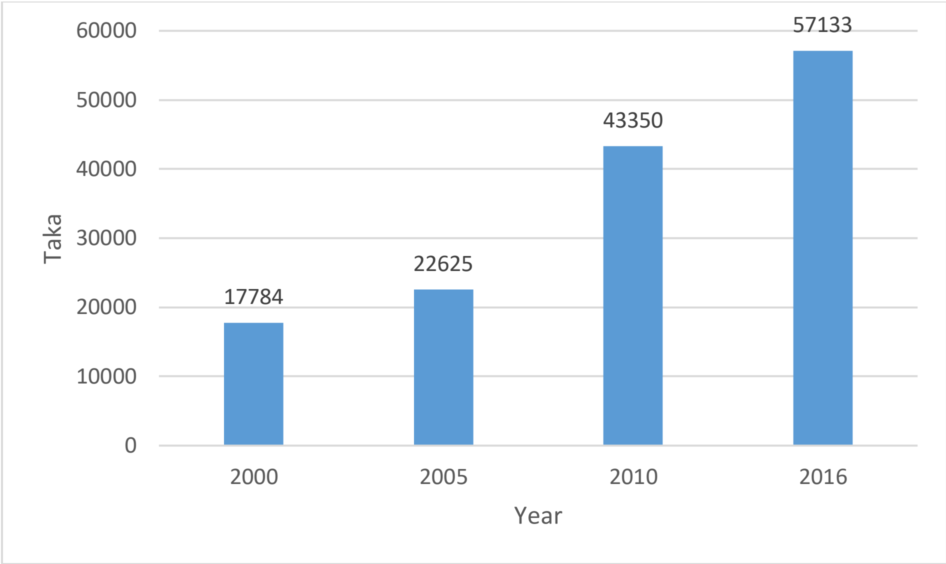

Figure 2.4 Per capita annual income in Bangladesh from 2000 to 2016

Finally, Table 2.1 also represents the share of food and non-food items of households. Bangladesh, being a developing country, has a significant amount of food budget, more than 57% of total expenditure on an average from 2000 to 2016.

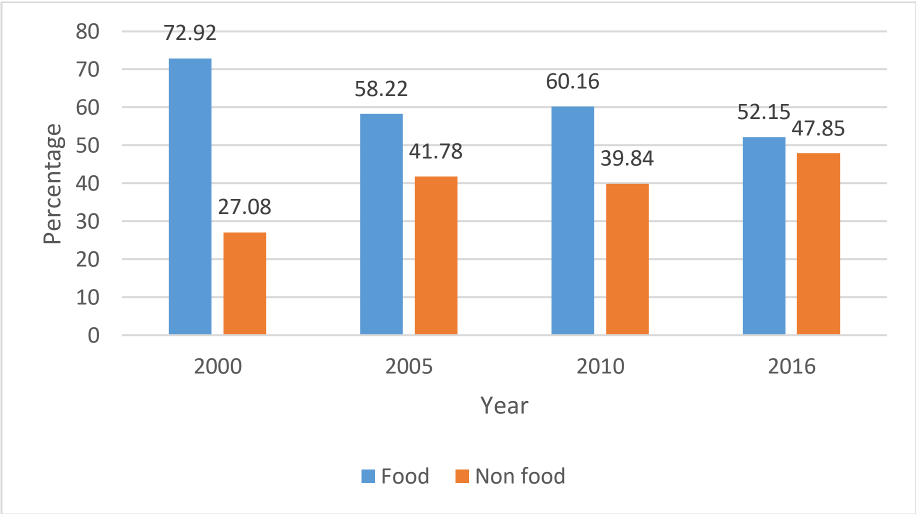

Figure 2.5 Budget share of food and non-food items from 2000 to 2016

Interestingly, it is evident from Figure 2.5 that the annual budget for food is decreasing and the budget for non-food is increasing indicating the rising income of the households. For example, Bangladeshi households spent around 73% of their total expenditure on food items and 27% on non-food items in 2000, while the budget share of food and non-food items was around 52% and 48% respectively in 2016.

Table 2.1 Descriptive Statistics for Food Price, Consumption, Budget Share, Income, and Share of Expenditure

Variable	**Year**									
	2000		**2005**		**2010**		**2016**		**All Year**	
	Mean	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**
Average food price										
Beef (Tk./kg)	70.39	8.80	99.28	9.82	238.50	14.07	412.72	54.80	289.31	147.10
Chicken (Tk./kg)	84.23	14.81	89.42	17.93	151.84	28.51	174.54	53.95	146.03	56.39
Mutton (Tk./kg)	108.74	19.14	138.72	20.86	318.32	21.83	519.35	86.58	372.09	181.95
Fish (Tk./kg)	52.76	20.07	59.94	19.16	115.72	35.33	158.51	62.49	122.21	65.70
Rice (Tk./kg)	12.52	1.82	17.28	1.78	32.91	4.26	34.45	7.43	28.84	10.30
Wheat (Tk./kg)	15.31	2.81	19.29	3.19	25.41	4.42	29.14	5.71	25.24	6.99
Pulse (Tk./kg)	39.58	2.08	47.23	3.93	106.42	10.83	121.16	17.30	96.98	35.97
Fruit (Tk./kg)	23.54	23.94	28.76	23.81	52.60	30.49	81.67	74.41	60.86	62.07
Vegetable (Tk./kg)	7.82	2.03	8.34	2.48	14.80	4.36	23.50	7.48	17.58	8.93
Onion (Tk./kg)	14.37	4.47	20.29	9.33	27.20	9.13	27.55	8.05	24.78	9.37
Milk (Tk./liter)	17.53	4.98	19.90	5.57	37.07	8.40	55.08	14.80	41.62	19.53
Eggs (Tk./piece)	3.00	0.49	3.44	0.46	6.29	0.68	8.68	1.01	6.72	2.47
Sugar (Tk./kg)	33.69	4.88	37.77	4.69	53.90	5.19	69.55	12.75	57.29	17.50
Oil (Tk./liter)	40.75	5.08	53.42	5.63	90.24	9.89	96.44	12.10	81.86	23.62
Per capita annual food consumption										
Beef (kg)	3.70	7.82	3.46	9.74	2.77	9.02	2.96	9.38	3.09	9.21
Chicken (kg)	1.79	4.57	2.95	6.60	4.55	8.22	6.39	8.65	4.95	8.07
Mutton (kg)	0.23	1.93	0.31	2.90	0.27	1.94	0.27	2.08	0.27	2.19
Fish (kg)	16.98	11.66	18.72	12.77	21.59	14.62	24.43	16.30	22.10	15.23
Rice (kg)	186.02	60.49	184.72	60.29	172.89	61.58	151.48	59.50	164.92	61.97
Wheat (kg)	0.77	4.37	0.27	2.22	10.71	20.91	7.40	16.49	6.12	15.65
Pulse (kg)	3.16	3.72	3.72	4.20	2.94	3.58	3.86	4.23	3.58	4.07
Fruit (kg)	12.20	20.74	14.95	27.20	19.27	33.57	14.65	25.23	15.29	26.96
Vegetable (kg)	86.50	39.57	98.03	44.66	103.98	47.10	99.90	50.37	98.82	47.95
Onion (kg)	7.11	4.81	8.12	5.75	9.70	6.16	12.98	8.05	10.89	7.43
Milk (liter)	11.64	20.60	13.35	24.05	13.03	23.51	9.98	19.87	11.30	21.45
Eggs (piece)	28.65	47.25	29.37	48.54	40.97	57.64	50.92	61.44	42.97	58.04
Sugar (kg)	2.10	3.68	2.78	4.65	3.38	5.27	2.56	4.52	2.70	4.62
Oil (liter)	4.30	4.70	5.76	5.45	8.24	5.92	10.93	6.90	8.81	6.76
Budget share (%)										
Beef	1.52	2.66	2.83	6.00	2.63	6.40	3.63	8.19	3.07	7.11
Chicken	0.78	1.65	2.15	3.97	3.00	4.53	4.16	4.96	3.22	4.61
Mutton	0.13	0.93	0.33	2.35	0.34	2.10	0.44	2.74	0.37	2.42

Fish	6.04	3.08	11.56	6.07	13.07	6.80	15.94	8.33	13.54	7.94
Rice	18.72	6.83	38.14	14.14	34.33	13.45	24.66	10.90	27.98	13.24
Wheat	0.06	0.31	0.04	0.36	1.51	3.19	0.89	2.19	0.78	2.18
Pulse	0.83	0.89	1.77	1.73	1.59	1.73	1.92	1.75	1.70	1.70
Fruit	1.30	1.74	2.78	3.81	3.31	4.30	3.01	4.08	2.83	3.92
Vegetable	5.00	1.72	8.93	3.17	8.54	3.23	10.32	4.37	9.14	4.11
Onion	0.73	0.39	1.67	1.03	1.43	0.79	1.57	0.87	1.46	0.88
Milk	1.19	1.90	2.34	3.74	2.18	3.66	1.92	3.47	1.95	3.42
Eggs	0.56	0.83	1.00	1.40	1.29	1.58	1.83	1.87	1.45	1.72
Sugar	0.40	0.61	0.90	1.25	0.83	1.10	0.64	1.04	0.69	1.06
Oil	1.15	1.04	3.05	2.30	4.01	2.23	4.60	2.15	3.84	2.37
Per capita annual income (Tk.)	17784	46581	22625	42976	43350	75134	57133	106083	44383	88662
Share of expenditure (%)										
Food	72.92	11.90	58.22	14.53	60.16	13.47	52.15	14.65	57.06	15.60
Non-food	27.08	11.90	41.78	14.53	39.84	13.47	47.85	14.65	42.93	15.60

Source: Household Income and Expenditure Survey (2000, 2005, 2010, and 2016), Bangladesh Bureau of Statistics

2.6 Results and Discussion

2.6.1 Estimation result from the EASI model

The EASI demand equations are estimated through the Full Information Maximum Likelihood (FIML) procedure with allowance being made for contemporaneous correlation across the stochastic terms of the system. To determine the proper degree of income polynomial, we increase the degree of polynomial at a time starting from L=2 and test the Bewley likelihood ratio (B_{LR}) test procedure to evaluate the incremental change in the explanatory power of the model (Table 2.2). Based on test results, L=5 i.e. *quantic* EASI model seems to be appropriate to capture the curvature of the Engel curves since the explanatory power of the model does not considerably enhance by adding one more degree of income polynomial. Interestingly, previous studies employing EASI model, as for example, Lewbel and Pendakur (2009) and Zhen et al. (2013) also found L=5 to be the most preferred specification in their analysis for Canadian and American household respectively. However, Hasan (2016) found the evidence of quadratic food Engel curve for Bangladeshi household from a semi-parametric model. Table 2.3 reports the parameter estimates from the system of 14 demand equations with a quintic Engle curve structure. The result indicated the intercept of all food items are positive. Moreover, all intercepts are significant at 1% level. Most of the income and price coefficient are also significant.

Table 2.2 Summary of the Model Diagnostic Tests

Hypothesis	Likelihood Ratio value	df.	p-value
(i) Linear vs. Quadratic EASI model (i.e., $\beta_{i2} = 0, \forall i = 1,..., J$)	3,974	14	0.00
(ii) Quadratic vs. Cubic GEASI model (i.e., $\beta_{i3} = 0, \forall i = 1,..., J$)	2,756	14	0.00
(iii) Cubic vs. Quartic GEASI model (i.e., $\beta_{i4} = 0, \forall i = 1,..., J$)	314	14	0.00
(iv) Quartic vs. Quintic GEASI model (i.e., $\beta_{i5} = 0, \forall i = 1,..., J$)	276	14	0.00
(v) Linear vs. Quadratic EASI model (i.e., $\beta_{i2} = 0, \forall i = 1,..., J$)	3,974	14	0.00
Demographic and socio-economic variables are not significant ($t_j = 0, \forall j = 1,..., n$)	5,894	14	0.00

Note: The EASI specification is estimated on household food expenditure panel data obtained from the Bangladesh Bureau of Statistics. The data cover 63 provinces/administrative districts over the span 2000-2016 and include 14 widely consumed food commodity groups. A total of 61,382 observations have been utilized in the demand system estimation.

Table 2.4 and 2.5 present Marshallian and Hicksian price elasticity estimates respectively from the EASI model. The diagonal elements of the Tables indicate own-price elasticity while the off-diagonal elements are cross-price elasticity evaluated at sample mean values. All Marshallian and Hicksian own-price elasticity estimates are negative and therefore, consistent with the theory of demand. Further, these elasticity estimates are also statistically significant. Marshallian own-price elasticities are more or less unitary elastic for all food commodities except for rice (-0.93) and onion (-0.77). In case of Hicksian own-price elasticity, rice appears to be more inelastic (-.53) than Marshallian elasticity. The change in the price of rice does not change the consumption of the households significantly because rice is a staple food in Bangladesh and also there is no close substitute of rice that are commonly consumed in the country. We can realize the scenario from Table 1 where the annual per capita consumption of rice is 164.92 kg, the consumption of wheat is only 6.12 kg. Other demand studies based on Bangladesh, found a wide range of own price elasticity for rice from -0.11 to -1.32 depending on the types and time of data and methods of estimation. For example, the estimated own price elasticities of Alamgir and Berlage (1973), Mahmud (1979), Karim (1983), Rahman (1989), Talukder (1990), Ahmed and Shams (1994), Ahmed (1997), Dorosh (1999), and Begum and D'Haese (2010) were -0.29, -0.39, -0.39, -1.18, -0.73, -0.12, -0.15, -0.50, and -0.11 respectively. Hicksian own-price elasticity for fish (-0.81), onion (-0.76) and vegetables (-0.65) are also inelastic whereas other food items are close to unitary elastic. Overall, Hicksian own-price elasticity estimates are more inelastic than that of Marshallian elasticity. Many of the cross-price elasticity estimates are significant and consistent with expectations. For example, substitution relationship is found between beef and chicken, between beef and mutton, between beef and egg, between milk and fruit etc. based on Marshallian elasticities. On the other hand, there is a complimentary relationship between rice and all other commodities except chicken which is consistent with household food habit in Bangladesh. In contrast, Hicksian cross-price elasticities shows complementary relationships among different food items.

Expenditure elasticities are estimated to be positive, significant and unitary elastic for all food items except vegetables (0.96). Based on expenditure elasticity, all commodities are found to be normal good meaning consumption increases with the increase of total expenditure. Since the people in developing countries like Bangladesh spend a large portion of total expenditure on food and also the food consumption is not saturated yet, the expenditure elasticities are mostly elastic.

Table 2.3 Parameter Estimates from the EASI System

Parameter	Beef	Chicken	Mutton	Fish	Rice	Wheat	Pulse	Fruit	Vegetable	Onion	Milk	Eggs	Sugar	Oil
Intercept	**193.950**	**306.820**	**-2229.910**	**2221.410**	**3785.080**	**-120.360**	**373.510**	**467.690**	**1399.650**	**251.430**	**-70.970**	**83.120**	**211.180**	**648.260**
	6.540	*4.970*	*117.600*	*9.130*	*11.000*	*4.410*	*2.760*	*7.390*	*8.700*	*2.680*	*5.280*	*3.330*	*2.560*	*2.080*
Income (β_{i1})	**0.840**	-0.470	-0.300	**3.220**	**73.770**	**1.180**	0.110	-0.070	**-48.050**	**-29.640**	**0.680**	**-1.740**	**-0.530**	**1.380**
	0.320	*0.440*	*0.650*	*1.110*	*3.590*	*0.300*	*0.200*	*0.240*	*3.340*	*1.050*	*0.230*	*0.320*	*0.230*	*0.240*
Income (β_{i2})	**-1.380**	**-2.360**	0.840	0.080	**-31.670**	**0.700**	**0.540**	-0.190	**16.800**	**14.180**	0.310	**1.250**	**1.110**	0.030
	0.280	*0.420*	*0.570*	*0.950*	*2.900*	*0.290*	*0.190*	*0.220*	*2.730*	*0.860*	*0.220*	*0.300*	*0.220*	*0.230*
Income (β_{i3})	**0.370**	**0.660**	**-0.860**	**-0.250**	**10.220**	**-0.250**	0.000	**-0.220**	**-3.680**	**-5.840**	**-0.610**	0.120	0.050	**-0.590**
	0.120	*0.150*	*0.260*	*0.300*	*0.970*	*0.110*	*0.070*	*0.080*	*0.930*	*0.300*	*0.090*	*0.110*	*0.080*	*0.080*
Income (β_{i4})	**0.020**	0.100	**0.230**	**-0.300**	**3.570**	0.010	**-0.070**	**0.160**	**-2.560**	**-0.750**	**0.150**	**-0.330**	**-0.160**	**0.170**
	0.040	*0.070*	*0.080*	*0.130*	*0.340*	*0.040*	*0.030*	*0.030*	*0.320*	*0.100*	*0.040*	*0.050*	*0.030*	*0.030*
Income (β_{i5})	0.000	0.000	0.000	0.010	**0.230**	0.000	0.000	0.000	**-0.180**	**-0.060**	**0.020**	**-0.030**	-0.010	**0.030**
	0.010	*0.010*	*0.020*	*0.010*	*0.030*	*0.010*	*0.000*	*0.000*	*0.030*	*0.010*	*0.010*	*0.000*	*0.000*	*0.000*
Price (α_{1i}) Beef	**-1.470**	**0.360**	**0.830**	0.360	**2.270**	0.050	**-0.750**	**-0.350**	**1.620**	**-2.970**	0.320	**0.480**	**0.450**	**-1.220**
	0.380	*0.180*	*0.370*	*0.230*	*0.280*	*0.150*	*0.190*	*0.120*	*0.280*	*0.180*	*0.210*	*0.220*	*0.170*	*0.210*
Price (α_{2i}) Chicken		0.180	-0.210	**-1.470**	**2.740**	-0.140	-0.010	**0.340**	**-1.350**	-0.040	-0.090	-0.150	-0.090	-0.080
		0.260	*0.310*	*0.320*	*0.360*	*0.170*	*0.120*	*0.110*	*0.380*	*0.230*	*0.140*	*0.170*	*0.120*	*0.150*
Price (α_{3i}) Mutton			-0.350	-0.320	-0.640	0.000	0.380	0.150	-1.010	**1.180**	-0.290	-0.460	-0.140	**0.870**
			0.810	*0.470*	*0.510*	*0.250*	*0.240*	*0.220*	*0.550*	*0.330*	*0.240*	*0.300*	*0.230*	*0.300*
Price (α_{4i}) Fish				**9.720**	**-3.090**	**0.670**	**-0.320**	**-1.370**	1.540	**-7.830**	0.100	**1.340**	**0.620**	0.050
				0.880	*0.930*	*0.220*	*0.150*	*0.180*	*0.940*	*0.510*	*0.170*	*0.240*	*0.180*	*0.180*
Price (α_{5i}) Rice					**312.500**	-0.260	**-0.820**	0.000	**-276.160**	**-32.210**	**-1.150**	**-2.420**	**-0.830**	0.050
					2.650	*0.240*	*0.170*	*0.200*	*2.330*	*0.750*	*0.190*	*0.260*	*0.200*	*0.240*
Price (α_{6i}) Wheat						0.170	0.160	-0.110	**0.500**	**-0.880**	-0.010	0.150	-0.170	-0.120
						0.140	*0.100*	*0.090*	*0.260*	*0.160*	*0.110*	*0.130*	*0.100*	*0.110*
Price (α_{7i}) Pulse							**0.770**	0.050	**1.300**	**-0.830**	**-0.380**	**0.320**	**0.250**	-0.100
							0.190	*0.090*	*0.170*	*0.100*	*0.130*	*0.150*	*0.110*	*0.150*
Price (α_{8i}) Fruit								0.110	-0.120	**1.500**	**0.180**	-0.180	-0.090	-0.110
								0.100	*0.210*	*0.130*	*0.090*	*0.120*	*0.090*	*0.100*
Price(α_{9i}) Vegetable									**278.890**	**-5.440**	0.150	-0.290	**-1.040**	**1.070**
									2.430	*0.780*	*0.200*	*0.270*	*0.210*	*0.220*
Price (α_{10i}) Onion										**45.550**	**0.890**	**0.880**	**0.750**	**-0.560**
										0.590	*0.130*	*0.170*	*0.130*	*0.130*
Price (α_{11i}) Milk											0.040	**0.390**	0.010	-0.170
											0.180	*0.140*	*0.110*	*0.140*
Price (α_{12i}) Eggs												-0.160	-0.140	0.230
												0.230	*0.150*	*0.180*
Price (α_{13i}) Sugar													-0.130	**0.560**
													0.130	*0.130*
Price (α_{14i}) Oil														**-0.470**
														0.220

Note: The italicized numbers are the estimated parameter standard errors. Values in bold identify elasticity estimates that are statistically different from 0 at or below the 0.05 significance level.

Table 2.4 Marshallian Price Elasticity Estimates from the EASI System

	Beef	Chicken	Mutton	Fish	Rice	Wheat	Pulse	Fruit	Vegetable	Onion	Milk	Eggs	Sugar	Oil
Beef	**-1.0036**	**0.0008**	**0.0020**	0.0005	**0.0047**	0.0001	**-0.0019**	**-0.0009**	**0.0036**	**-0.0072**	0.0007	**0.0011**	**0.0011**	**-0.0030**
	0.0009	*0.0004*	*0.0009*	*0.0006*	*0.0007*	*0.0004*	*0.0005*	*0.0003*	*0.0007*	*0.0004*	*0.0005*	*0.0005*	*0.0004*	*0.0005*
Chicken	**0.0009**	**-0.9995**	-0.0005	**-0.0032**	**0.0068**	-0.0003	0.0000	**0.0008**	**-0.0030**	-0.0001	-0.0002	-0.0003	-0.0002	-0.0001
	0.0004	*0.0006*	*0.0007*	*0.0008*	*0.0009*	*0.0004*	*0.0003*	*0.0003*	*0.0009*	*0.0005*	*0.0003*	*0.0004*	*0.0003*	*0.0003*
Mutton	**0.0174**	-0.0040	**-1.0072**	-0.0055	-0.0106	0.0000	0.0080	0.0034	-0.0198	**0.0244**	-0.0057	-0.0094	-0.0028	**0.0181**
	0.0075	*0.0064*	*0.0165*	*0.0102*	*0.0114*	*0.0050*	*0.0050*	*0.0045*	*0.0114*	*0.0069*	*0.0049*	*0.0062*	*0.0048*	*0.0061*
Fish	0.0001	**-0.0009**	-0.0002	**-0.9951**	**-0.0023**	**0.0003**	**-0.0002**	**-0.0008**	0.0006	**-0.0042**	0.0000	**0.0007**	**0.0003**	-0.0001
	0.0001	*0.0002*	*0.0003*	*0.0005*	*0.0005*	*0.0001*	*0.0001*	*0.0001*	*0.0005*	*0.0003*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
Rice	**-0.0002**	-0.0001	**-0.0003**	**-0.0043**	**-0.9276**	**-0.0003**	**-0.0007**	**-0.0007**	**-0.0729**	**-0.0086**	**-0.0008**	**-0.0010**	**-0.0004**	**-0.0010**
	0.0001	*0.0001*	*0.0001*	*0.0003*	*0.0007*	*0.0001*	*0.0000*	*0.0001*	*0.0006*	*0.0002*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
Wheat	0.0000	-0.0019	-0.0001	**0.0044**	**-0.0071**	**-0.9985**	0.0013	-0.0016	0.0034	**-0.0088**	-0.0004	0.0013	-0.0018	-0.0018
	0.0015	*0.0017*	*0.0024*	*0.0022*	*0.0025*	*0.0014*	*0.0010*	*0.0009*	*0.0026*	*0.0016*	*0.0010*	*0.0013*	*0.0010*	*0.0011*
Pulse	**-0.0032**	-0.0001	0.0016	**-0.0015**	**-0.0036**	0.0007	**-0.9968**	0.0002	**0.0054**	**-0.0035**	**-0.0016**	**0.0014**	**0.0010**	-0.0005
	0.0008	*0.0005*	*0.0010*	*0.0007*	*0.0008*	*0.0004*	*0.0008*	*0.0004*	*0.0007*	*0.0004*	*0.0005*	*0.0006*	*0.0005*	*0.0007*
Fruit	**-0.0009**	**0.0009**	0.0004	**-0.0034**	0.0001	-0.0003	0.0001	**-0.9997**	-0.0003	**0.0038**	**0.0005**	-0.0004	-0.0002	-0.0003
	0.0003	*0.0003*	*0.0005*	*0.0005*	*0.0005*	*0.0002*	*0.0002*	*0.0003*	*0.0005*	*0.0003*	*0.0002*	*0.0003*	*0.0002*	*0.0003*
Vegetable	**0.0028**	**0.0006**	-0.0006	**0.0082**	**-0.2006**	**0.0008**	**0.0019**	**0.0014**	**-0.7778**	**-0.0035**	**0.0011**	**0.0005**	**-0.0004**	**0.0028**
	0.0002	*0.0003*	*0.0004*	*0.0009*	*0.0020*	*0.0002*	*0.0001*	*0.0002*	*0.0019*	*0.0006*	*0.0002*	*0.0002*	*0.0002*	*0.0002*
Onion	**-0.0084**	**0.0061**	**0.0065**	**-0.0111**	**-0.1002**	**-0.0028**	-0.0006	**0.0130**	**-0.0080**	**-0.7754**	**0.0082**	**0.0072**	**0.0051**	**0.0048**
	0.0009	*0.0011*	*0.0016*	*0.0027*	*0.0041*	*0.0008*	*0.0005*	*0.0007*	*0.0039*	*0.0029*	*0.0006*	*0.0009*	*0.0007*	*0.0007*
Milk	0.0011	-0.0004	-0.0011	-0.0001	**-0.0053**	-0.0001	**-0.0015**	**0.0006**	0.0002	**0.0033**	**-0.9999**	**0.0014**	0.0000	-0.0008
	0.0008	*0.0005*	*0.0009*	*0.0007*	*0.0008*	*0.0004*	*0.0005*	*0.0003*	*0.0008*	*0.0005*	*0.0006*	*0.0005*	*0.0004*	*0.0005*
Eggs	**0.0028**	-0.0004	-0.0023	**0.0083**	**-0.0087**	0.0009	**0.0018**	-0.0005	-0.0003	**0.0046**	**0.0022**	**-1.0006**	-0.0006	0.0016
	0.0011	*0.0008*	*0.0015*	*0.0013*	*0.0014*	*0.0006*	*0.0007*	*0.0006*	*0.0014*	*0.0009*	*0.0007*	*0.0012*	*0.0007*	*0.0009*
Sugar	**0.0047**	-0.0007	-0.0014	**0.0072**	**-0.0062**	-0.0017	**0.0026**	-0.0007	**-0.0097**	**0.0076**	0.0003	-0.0013	**-1.0013**	**0.0059**
	0.0017	*0.0012*	*0.0023*	*0.0018*	*0.0021*	*0.0010*	*0.0011*	*0.0009*	*0.0021*	*0.0013*	*0.0011*	*0.0015*	*0.0013*	*0.0013*
Oil	**-0.0024**	-0.0003	**0.0017**	-0.0004	-0.0009	-0.0003	-0.0003	-0.0003	**0.0017**	**-0.0011**	-0.0004	0.0004	0.0010	**-1.0010**
	0.0004	*0.0003*	*0.0006*	*0.0003*	*0.0005*	*0.0002*	*0.0003*	*0.0002*	*0.0004*	*0.0002*	*0.0003*	*0.0003*	*0.0003*	*0.0004*

Note: The italicized numbers are the estimated parameter standard errors. Values in bold identify elasticity estimates that are statistically different from 0 at or below the 0.05 significance level.

Table 2.5 Hicksian Price Elasticity Estimates from the EASI System

	Beef	**Chicken**	**Mutton**	**Fish**	**Rice**	**Wheat**	**Pulse**	**Fruit**	**Vegetable**	**Onion**	**Milk**	**Eggs**	**Sugar**	**Oil**
Beef	**-0.9619**	**0.0441**	**0.0069**	**0.1877**	**0.3974**	**0.0103**	**0.0218**	**0.0390**	**0.1322**	**0.0134**	**0.0277**	**0.0211**	**0.0111**	**0.0492**
	0.0009	*0.0004*	*0.0009*	*0.0006*	*0.0007*	*0.0004*	*0.0005*	*0.0003*	*0.0007*	*0.0004*	*0.0005*	*0.0005*	*0.0004*	*0.0005*
Chicken	**0.0425**	**-0.9564**	**0.0044**	**0.1835**	**0.3983**	**0.0099**	**0.0236**	**0.0406**	**0.1252**	**0.0205**	**0.0267**	**0.0196**	**0.0098**	**0.0519**
	0.0004	*0.0006*	*0.0007*	*0.0007*	*0.0008*	*0.0004*	*0.0003*	*0.0003*	*0.0009*	*0.0005*	*0.0003*	*0.0004*	*0.0003*	*0.0003*
Mutton	**0.0587**	**0.0390**	**-1.0024**	**0.1802**	**0.3789**	**0.0101**	**0.0315**	**0.0430**	**0.1077**	**0.0448**	**0.0210**	0.0105	0.0071	**0.0699**
	0.0075	*0.0064*	*0.0165*	*0.0096*	*0.0105*	*0.0050*	*0.0049*	*0.0044*	*0.0113*	*0.0069*	*0.0049*	*0.0062*	*0.0048*	*0.0061*
Fish	**0.0418**	**0.0424**	**0.0047**	**-0.8079**	**0.3903**	**0.0106**	**0.0234**	**0.0391**	**0.1291**	**0.0164**	**0.0270**	**0.0207**	**0.0103**	**0.0522**
	0.0001	*0.0002*	*0.0003*	*0.0005*	*0.0005*	*0.0001*	*0.0001*	*0.0001*	*0.0005*	*0.0003*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
Rice	**0.0422**	**0.0439**	**0.0047**	**0.1861**	**-0.5283**	**0.0101**	**0.0234**	**0.0398**	**0.0578**	**0.0123**	**0.0266**	**0.0193**	**0.0098**	**0.0521**
	0.0001	*0.0001*	*0.0001*	*0.0002*	*0.0007*	*0.0001*	*0.0000*	*0.0001*	*0.0006*	*0.0002*	*0.0000*	*0.0001*	*0.0001*	*0.0001*
Wheat	**0.0421**	**0.0418**	**0.0048**	**0.1935**	**0.3894**	**-0.9882**	**0.0252**	**0.0387**	**0.1332**	**0.0119**	**0.0268**	**0.0214**	**0.0083**	**0.0509**
	0.0015	*0.0017*	*0.0024*	*0.0021*	*0.0023*	*0.0014*	*0.0010*	*0.0009*	*0.0025*	*0.0016*	*0.0010*	*0.0013*	*0.0010*	*0.0011*
Pulse	**0.0384**	**0.0431**	**0.0065**	**0.1855**	**0.3885**	**0.0109**	**-0.9732**	**0.0400**	**0.1338**	**0.0170**	**0.0253**	**0.0213**	**0.0110**	**0.0517**
	0.0008	*0.0005*	*0.0010*	*0.0006*	*0.0007*	*0.0004*	*0.0008*	*0.0004*	*0.0007*	*0.0004*	*0.0005*	*0.0006*	*0.0005*	*0.0007*
Fruit	**0.0407**	**0.0441**	**0.0053**	**0.1834**	**0.3919**	**0.0099**	**0.0237**	**-0.9599**	**0.1280**	**0.0243**	**0.0274**	**0.0195**	**0.0098**	**0.0519**
	0.0003	*0.0003*	*0.0005*	*0.0005*	*0.0005*	*0.0002*	*0.0002*	*0.0003*	*0.0005*	*0.0003*	*0.0002*	*0.0003*	*0.0002*	*0.0003*
Vegetable	**0.0429**	**0.0422**	**0.0041**	**0.1881**	**0.1767**	**0.0106**	**0.0246**	**0.0397**	**-0.6543**	**0.0163**	**0.0270**	**0.0197**	**0.0092**	**0.0530**
	0.0002	*0.0003*	*0.0004*	*0.0007*	*0.0018*	*0.0002*	*0.0001*	*0.0002*	*0.0019*	*0.0006*	*0.0002*	*0.0002*	*0.0002*	*0.0002*
Onion	**0.0272**	**0.0430**	**0.0106**	**0.1488**	**0.2352**	**0.0059**	**0.0195**	**0.0471**	**0.1018**	**-0.7578**	**0.0313**	**0.0242**	**0.0136**	**0.0494**
	0.0009	*0.0011*	*0.0016*	*0.0025*	*0.0037*	*0.0008*	*0.0005*	*0.0006*	*0.0038*	*0.0029*	*0.0006*	*0.0008*	*0.0007*	*0.0006*
Milk	**0.0428**	**0.0429**	**0.0038**	**0.1872**	**0.3877**	**0.0102**	**0.0222**	**0.0405**	**0.1288**	**0.0239**	**-0.9729**	**0.0214**	**0.0100**	**0.0515**
	0.0008	*0.0005*	*0.0009*	*0.0006*	*0.0007*	*0.0004*	*0.0005*	*0.0003*	*0.0007*	*0.0005*	*0.0006*	*0.0005*	*0.0004*	*0.0005*
Eggs	**0.0440**	**0.0425**	0.0026	**0.1936**	**0.3798**	**0.0110**	**0.0252**	**0.0389**	**0.1269**	**0.0250**	**0.0289**	**-0.9809**	**0.0093**	**0.0533**
	0.0011	*0.0008*	*0.0015*	*0.0012*	*0.0013*	*0.0006*	*0.0007*	*0.0006*	*0.0014*	*0.0009*	*0.0007*	*0.0012*	*0.0007*	*0.0009*
Sugar	**0.0461**	**0.0423**	0.0035	**0.1931**	**0.3836**	**0.0085**	**0.0261**	**0.0389**	**0.1179**	**0.0280**	**0.0271**	**0.0185**	**-0.9913**	**0.0577**
	0.0017	*0.0012*	*0.0023*	*0.0018*	*0.0020*	*0.0010*	*0.0011*	*0.0009*	*0.0021*	*0.0013*	*0.0011*	*0.0015*	*0.0013*	*0.0013*
Oil	**0.0393**	**0.0430**	**0.0065**	**0.1870**	**0.3920**	**0.0100**	**0.0234**	**0.0396**	**0.1304**	**0.0195**	**0.0266**	**0.0204**	**0.0111**	**-0.9488**
	0.0004	*0.0003*	*0.0006*	*0.0003*	*0.0005*	*0.0002*	*0.0003*	*0.0002*	*0.0004*	*0.0002*	*0.0003*	*0.0003*	*0.0003*	*0.0004*

Note: The italicized numbers are the estimated parameter standard errors. Values in bold identify elasticity estimates that are statistically different from 0 at or below the 0.05 significance level.

Table 2.6 Expenditure Elasticity Estimates from the EASI System

Food Item	Estimates	Std. Error
Beef	1.0020	0.0008
Chicken	0.9989	0.0010
Mutton	0.9938	0.0133
Fish	1.0017	0.0006
Rice	1.0188	0.0009
Wheat	1.0115	0.0029
Pulse	1.0005	0.0008
Fruit	0.9998	0.0006
Vegetable	0.9626	0.0026
Onion	0.8558	0.0051
Milk	1.0025	0.0009
Eggs	0.9913	0.0016
Sugar	0.9947	0.0023
Oil	1.0026	0.0005

Note: All estimates are statistically different from 0 at 0.01 significance level

2.6.2 Consumer welfare analysis

Prices have increased remarkably for all food commodities over the study period in Bangladesh. For example, the price of beef increased from 70.39 Tk. /kg in the year 2000 to 412.72 Tk. /kg in the year 2016, almost six times higher from the year 2000. Similarly, the prices of other commodities have increased approximately in range of 200% to 500% from 2000 to 2016. After beef, the highest increase in price was observed for mutton (478%) followed by fruit (347%), milk (314%), pulse (306%), vegetables (301%), fish (300%), egg (289%), rice (275%), oil (236%), chicken (207%), sugar (206%), onion (192%), and wheat (190%). However, the rise in price was not follow the same trend for every five-year span. Following the global trend, the food prices in Bangladesh increases at the highest rate from 2005 to 2010 span compare to other five-year spans. The food inflation was the highest in 2007-2008 in Bangladesh due to global food crisis triggered by loss of local food production for natural calamities. Balagtas et al. (2014) found that the price of a balanced food basket increased by more than 50% during 2000–2008, while household income rose only 15%. As a result, the incidence and severity of rural poverty in Bangladesh sunk to pre-2000 levels during 2004–2008. Thus, the price spikes in 2007–2008 helped push an additional 13 million people into poverty in rural Bangladesh.

We evaluated consumer welfare consequences of rising food price in Bangladesh over the sample period through estimating CV for actual price changes, as well as for two hypothetical scenarios of uniform increases in all food commodities by 15% and 25%. CV represents the amount of income that must be given to the household after price change in order to take him back to his old level of utility at the new prices. We estimated CV utilizing Hicksian elasticity estimates obtained from the EASI model and found positive in all cases. Figure 2.6 represents district wise households mean welfare loss over the study period from actual price change, and 15% and 30% simulated price change ordered by income. It is evident from Figure 2.6 that lower income household were affected the most due to rise in price. Figure 2.7 shows division wise household mean welfare loss from 2000 to 2016 based on actual price changes as well as 15% and 30% simulated price rise. Welfare loss in Sylhet and Rajshahi was little bit higher than other divisions while welfare loss is similar among other divisions. Furthermore, the distribution of income and welfare loss resulting from actual price change, and the correlation thereof through 2000 to 2016 has been visualized in Figure 2.8. Finally, the distribution of mean welfare loss resulting from actual price changes, and hypothetical uniform price increases as a share of consumer income has been presented in Table 2.7. The welfare effect of both actual price changes and simulated price changes are found to be positive and therefore, indicates welfare loss of the households.

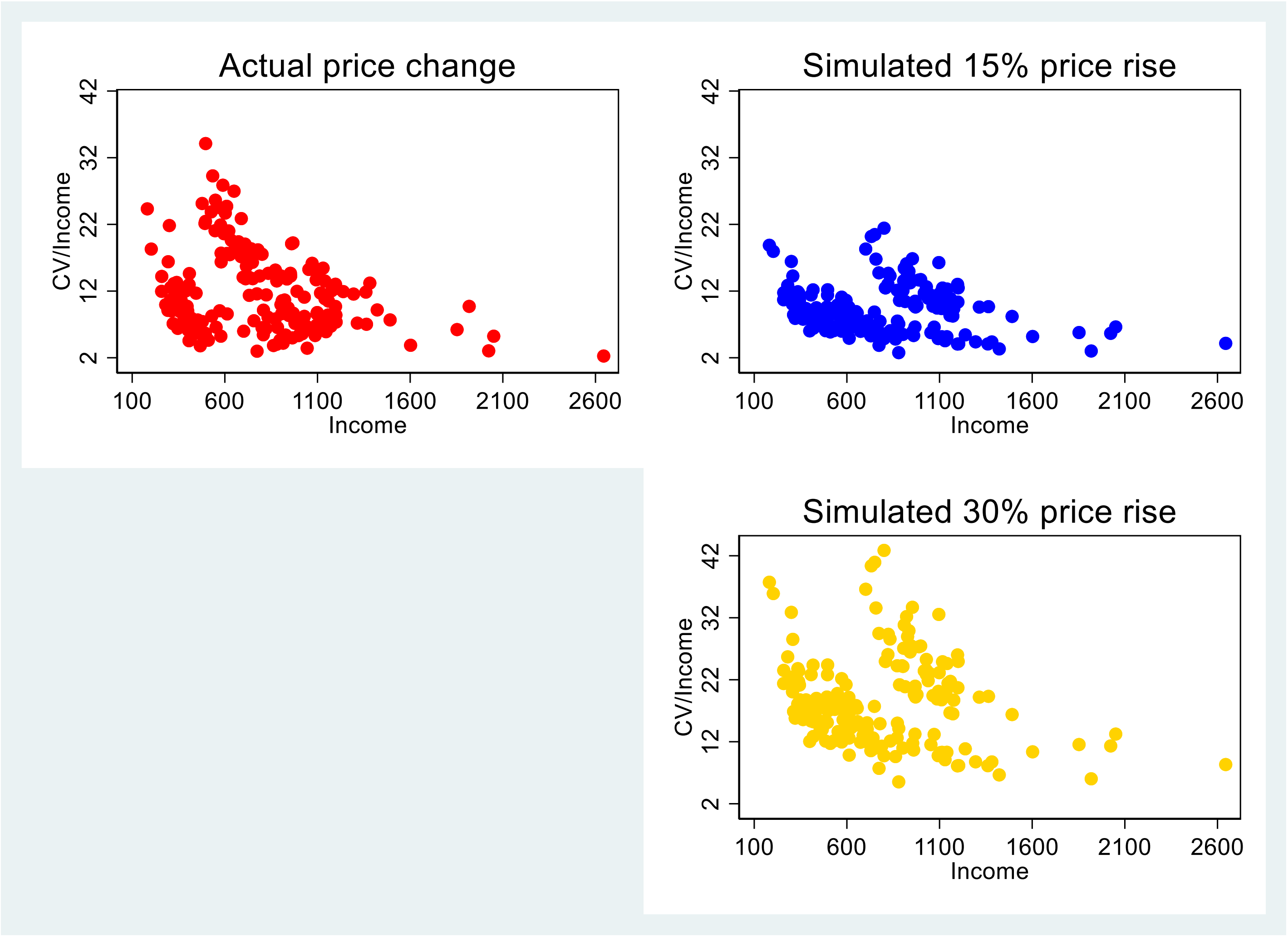

Figure 2.6 District wise mean welfare loss as percent of income resulting from actual price change (top left), simulated 15% (top right) and 30% (bottom) price rise, 2000-2016

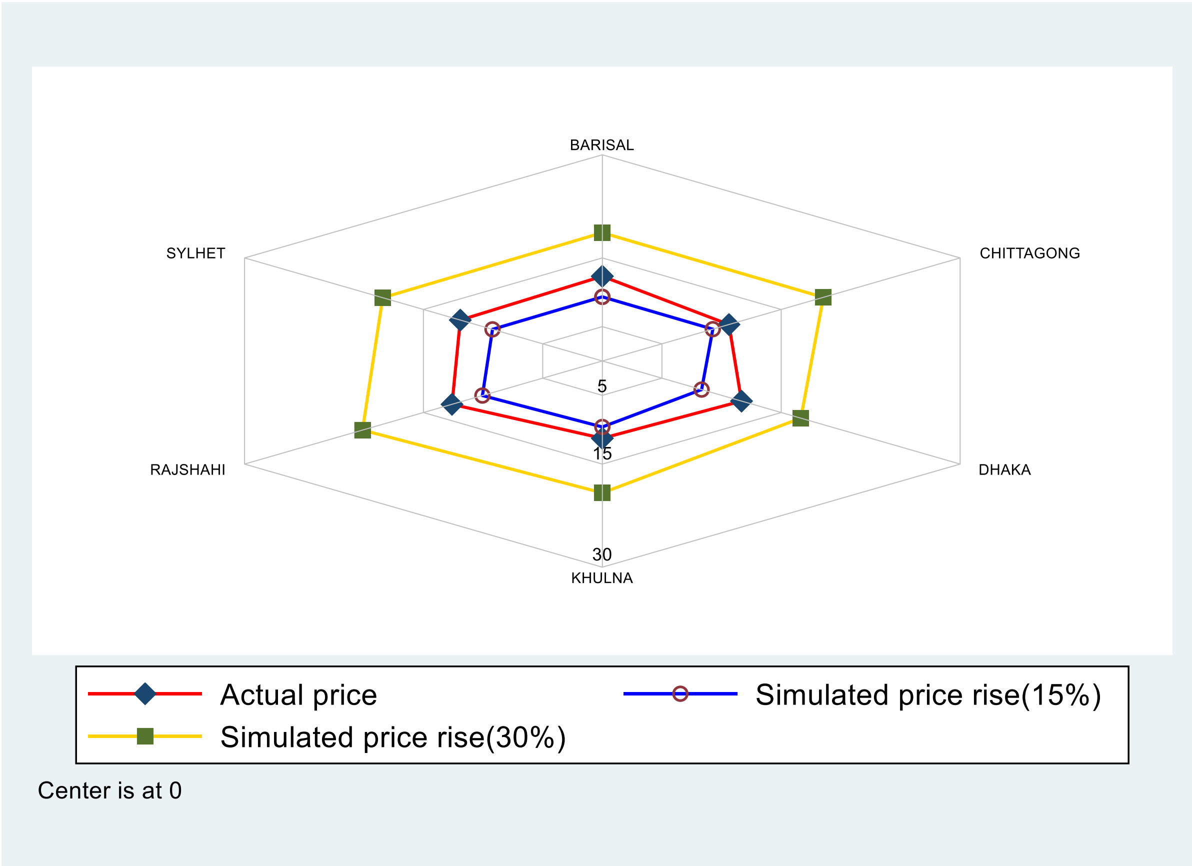

Figure 2.7 Division-specific mean household welfare loss over 2000-2016 resulting from actual price changes, simulated 15% and 30% price rise

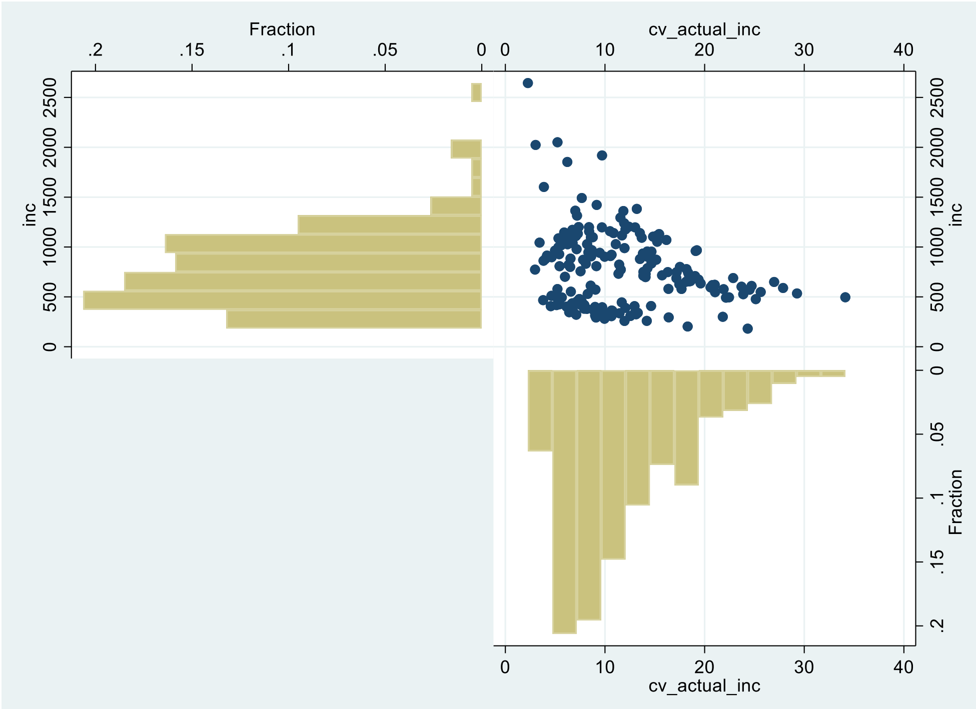

Figure 2.8 Distribution of income and welfare loss resulting from actual price change, and the correlation thereof, 2000-2016.

Table 2.7 Distribution of Mean Welfare Loss Resulting from Actual Price Changes, and Hypothetical Uniform Price Increases as a Share of Consumer Income

Percentile of welfare losses	Actual price change	15% simulated price rise	30% simulated price rise
10th	5.33%	5.19%	10.38%
25th	7.09%	6.62%	13.24%
50th	10.47%	8.85%	17.69%
Mean	11.75%	9.27%	18.53%
75th	15.14%	11.22%	22.43%
90th	20.95%	13.74%	27.49%

Note 1: Welfare effect is measured by Hicksian Compensating Variation, where a positive value indicates welfare loss.

Note 2: The two hypothetical price change scenarios are based on an assumption of uniform price increases by 15% and 30%, respectively.

2.7 Conclusions

The economy of Bangladesh is growing rapidly after the economic reform in 1991 in the form of market liberalization and industrialization. During last decades the per capita national income and other socio-economic factors have been changed significantly that affects food demand and consumption pattern of the households in the country. Further, the sharp increase in food commodity prices in Bangladesh during the past decade have raised concern of the researchers and policy makers to focus on consumer welfare analysis to formulate appropriate policies on food security and poverty issues. Consequently, the objective of this study is to analyze food demand in Bangladesh by utilizing the EASI approach and to evaluate welfare consequences of rising food price in Bangladesh.

This study estimates the demand structure for 14 major food items using secondary data extracted from Household Income and Expenditure Survey (HIES) during the years 2000, 2005, 2010, and 2016. To determine the proper degree of income polynomial, we used the Bewley likelihood ratio (B_{LR}) test procedure to evaluate the incremental change in the explanatory power of the model and preferred *quantic* EASI model to capture the curvature of the Engel curves. Our findings indicate that all Marshallian and Hicksian own-price elasticity estimates are negative and statistically significant. Marshallian own-price elasticities are more or less unitary elastic for all food commodities except for rice and onion. Hicksian price elasticities are found to be more inelastic compare to Marshallian elasticities. Many of the cross-price elasticity estimates are significant and consistent with expectations. For example, substitution relationship is found between beef and fish, between egg and beef, and between chicken and vegetables etc. while complimentary relationship found between rice and all other commodities. Expenditure elasticities are estimated to be positive, significant and unitary elastic for all food items except vegetables

(0.9491). Based on expenditure elasticity, all commodities are found to be normal meaning consumption increases with the increase of total expenditure. Welfare analysis indicates lower income household were affected the most due to rise in price. However, welfare loss of rural households was little bit higher than that of urban households. The welfare effect of both actual price changes and simulated price changes are found to be positive and therefore, indicates welfare loss of the households.

These results have a potential to expand the literature on food demand in Bangladesh and inform policy decisions on food and nutritional security, agriculture, trade, and foreign direct investment decisions to boost up economic growth and poverty alleviation of the country.

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Chapter 3 - Food Demand Estimation in Bangladesh Addressing Pre-Committed Demand

3.1 Problem Statement

The government of Bangladesh implemented economic reform in 1991 based on market-oriented policies which enhanced the economic growth of the country progressively (Halder et al. 2003). Particularly, during the last decade, the annual growth rate of GDP was consistently over 6% in the country (BBS 2018). As a result, the trends of per capita income, industrialization and urbanization are rising day by day that affects the food demand and consumption pattern of the households (Zheng et al. 2015). Households are gradually shifting their food preferences from carbohydrate to protein enriched food items like fish, meat and egg (BBS 2017b). Additionally, like other developing countries, the pre-committed demand i.e. the portion of demand that consumers are willing to consume regardless of any change in economic factors, is anticipated to observe in the food demand of Bangladeshi household. Therefore, it is really important for policy makers and agribusiness market participants to have a good understanding about the food demand system and consumer preferences in Bangladesh considering the changing socioeconomic and demographic scenarios, and pre-committed demand to ensure food and nutritional security, price stability, continuous profit and appropriate import-export policies of the country.

Bangladesh is a rapidly growing developing economy in South Asia. The country consistently achieved over 6% growth rate in GDP, from 2010-11 to 2017-18 (BBS 2018). Per capita national income rises from 759 US dollar in 2008-09 to 1610 US dollar in 2016-17, more than double within 8 years (BBS 2017a; BBS 2018). Increasing labor intensive industrialization like expansion of garments and textile industries, business and services, rural-urban and overseas migration enhance economic growth of the country (Nargis and Hossain 2006). The urbanization process in Bangladesh is also mounting up. In 2001, about 20% of the population lived in urban areas; the share increased to 35.04% by 2016 (World Bank 2017). Following the global trend of increasing food price, Bangladesh had also badly experienced price hike in food commodities, especially in rice during last decade. The national wholesale price of rice increased from Taka 15.9 per kg in January 2006 to Taka 30.8 per kg in August 2008, over 94% increase during this period (Sulaiman et al. 2009). Inflation moved to two-digit level in 2007-08 and 2010-11 calculated as 12.28% and 10.89% respectively, mostly led by food inflation (Hossain et al. 2013). Furthermore, the pressure of population is also intensifying, projected to grow to 178-230 million in 2050 from 160 million in 2016 (UN 2016).

Changes in income, urbanization, price, demography and associated changes in lifestyles lead to change in food demand and consumption pattern (Huang & Bouis 2001; Godfray et al. 2010; Regmi & Dyck 2001; Regmi et al. 2001; Zheng et al. 2015). Food preferences tend to shift from cereals toward higher value items such as fish, meat, dairy products, and fruits with increase in income (Gerbens-Leenes et al. 2010; Huang & David 1993; Ito et al.1989; Kearney 2010; Mittal 2007; Pingali 2006; Rao 2000). Rapid urbanization can also change dietary pattern at the household level. Urban households may consume more fat, protein and western-style foods due to lifestyle changes and increasing opportunity costs of preparing food in house by especially female members (Huang & David 1993; Regmi & Dyck 2001). Mottaleb et al. (2018) found that Bangladesh, the traditional rice-consuming country is consuming less rice than before. Demand for higher value products such as meat, fish and egg is also increasing (Mottaleb et al. 2018; BBS 2017b). Therefore, it is really important for policy makers to understand the complete food demand system of the consumer in Bangladesh under the changing socio-economic scenarios to ensure food and nutritional security, price stability, poverty alleviation and appropriate import-export policy of the country. However, despite the need of accurate demand estimation with advanced model, there is no recent demand study in Bangladesh to understand the consumer behavior subject to changing consumption pattern.

Consumer demand for food is an important component for policy makers to formulate policies on food security, health, nutrition, welfare and trade issues. Policies on these issues cannot produce desired outcome without modelling the real phenomena of consumer behavior. The pre-committed demand is a widely observed phenomenon of consumer behavior in developing countries (Hovhannisyan and Gould 2011; Hovhannisyan and Shanoyan 2018) as well as developed countries (Rowland et al. 2017; Tonsor and Marsh 2007). Pre-commitment is defined as the amount that consumers are willing to consume regardless of any change in economic factors (Gorman, 1976). Demand is almost perfectly inelastic over the pre-committed portion of demand. Consumers response significantly to change in price once this pre-committed portion of demand is satisfied (Rowland et al. 2017). Despite the empirical evidence of having existence of pre-committed demand, many of the advanced demand models are unable to represent this important phenomenon (Hovhannisyan and Shanoyan 2018). Consequently, estimation of consumer demand employing these models leads to biased estimate when pre-committed demand exists in consumer behavior.

Demand for food can be more precisely estimated through explicitly modeling this pre-commitment component. Own-price elasticities are supposed to be more elastic incorporating pre-committed demand in the model compare to elasticity estimates that do not account pre-commitment levels. For instance, Rowland et al. (2017) found that all uncompensated and compensated own price elasticities are more elastic by explicitly considering pre-commitment levels. Estimated elasticity ignoring pre-commitments would be a weighted average of two components: pre-commitment level with perfectly inelastic demand and discretionary level with elastic demand. Thus, a weighted average measure misinterprets both components having too large estimates in inelastic portion of demand curve and too small estimates in elastic portion of demand curve. Economic model integrating pre-committed demand, estimates elasticities for only discretionary component of consumption whereas the estimated elasticities based on all consumption in the model where pre-commitment levels are not explicitly considered (Rowland et al. 2017). As a result, if policy makers would like to reduce the consumption of a particular commodity, raising the price to the inelastic portion of demand curve cannot achieve this policy outcome. For example, Rowland et al. (2017) showed around 45% increase in price is necessary to reduce energy oil consumption about 8% in U.S. considering the presence of pre-commitment while ignoring the pre-commitment leads to conclude that only 10.5% increase in price is necessary. Similarly, other policies cannot be effective ignoring pre-committed demand.

Being a developing country, it is more likely to observe pre-committed demand in Bangladesh for two reasons. First, Bangladeshi households spend a large share of income on food items generally due to low total income. The national average nominal income was calculated around $200 per month per household and the share of food expenditure was 47.70% whereas that of non-food expenditure was 52.30% (BBS 2017b). As a result, most of the people in Bangladesh have a high level of dependence on food including pre-committed demand. Second, Bangladeshi households have some major food items such as rice, vegetables, egg, oil etc. in their food basket, for which pre-commitment levels are expected to be present. For example, Hovhannisyan and Gould (2011) explored the presence of positive significant pre-committed quantities for vegetables, rice, other grains and fat/oil products in China. Hovhannisyan and Shanoyan (2018) observed pre-committed demand for major food items such as cereals, eggs and fat/oils in Russia. But previous studies on consumer demand analysis in Bangladesh did not account for this important phenomenon in their demand models, which could lead to biased estimates of elasticities of food commodities.

A significant number of studies on consumer food demand analysis has been performed for different developing and developed countries mostly using widespread Almost Ideal Demand System (AIDS) and its family models. Although AIDS and other advanced demand models have some advantages to use but these models have limitation to modelling flexible Engle curves and to recognize unobserved consumer heterogeneity (Zhen et al. 2013). The generalized AIDS (Bollino 1987) and the generalized quadratic AIDS (Banks et. al. 1997) models can capture the pre-committed demand, however, these models have also similar limitations like other AIDS models. The Exact Affine Stone Index (EASI) model developed by Lewbel and Pendakur (2009) has some distinct advantages over other traditional demand models in terms of modelling flexible Engle curves and allowing for unobserved consumer heterogeneity. However, the present specification of the model does not permit to quantify the pre-committed demand and thus it may lead to demand estimates that do not truly represent consumer behavior. This paper follows the approach in Hovannisyan and Shanoyan (2018) by using generalized EASI (GEASI) demand model to address the pre-committed food demand in Bangladesh. Thus, the main objective of this study is to estimate elasticities of major food items in Bangladesh in the presence of pre-committed demand component. This study contributes to agricultural economics literature by addressing pre-committed demand in Bangladesh using relatively new GEASI model.

3.2 Objectives of the Study

The general objective of the study is to estimate consumer food demand by accounting for potential pre-committed demand in Bangladesh. However, the specific objectives are:

i) to estimate consumers' potential pre-committed and discretionary demand for different food items in Bangladesh.

ii) to measure the Marshallian and Hicksian price and expenditure elasticities for different food items utilizing GEASI model in Bangladesh.

3.2 Literature Review

3.2.1 Pre-committed demand estimation

Several studies have examined the presence of pre-commitments in empirical demand estimation for different food and non-food commodities both in developing (Hovhannisyan and Shanoyan 2018; Hovhannisyan and Gould 2011) and developed countries (Rowland et. al. 2017; Tonsor and Marsh 2007; Piggot and Marsh 2004; Park et al. 1996). Most of the studies used GAIDS model to measure the pre-commitment levels where as Hovhannisyan and Shanoyan (2018) derived the GEASI model and used it to quantify pre-committed demand in Russia.

In case of developing countries, Hovhannisyan and Gould (2011) investigated the presence of pre-committed demand component in food items in urban China. They estimated a generalized quadratic AIDS (GQAIDS) model for a system of 11 food commodities on household expenditure data from 1995 through 2003. No significant positive pre-committed demand found for the food commodities in urban Chinese households in mid-nineties. However, the presence of positive significant pre-committed quantities observed for vegetables, rice, other grains and fat/oil products in 2003. Hovhannisyan and Shanoyan (2018) findings supported the presence of pre-committed demand for major food items such as cereals, eggs and fat/oils in Russia. The pre-committed demands were estimated as 17.6%, 18.4%, and 27.8% of cereal, eggs, and fat/oils demands, respectively. The study also analyzed the effects of ignoring pre-committed demand on elasticity estimates by comparing estimates between GEASI and EASI approaches. The results showed that omitting pre-commitments caused significant biases in the estimates of Marshallian own price and expenditure elasticities.

In case of developed countries, Park et al. (1996) explored the presence of pre-committed demand in U.S. households and found significantly different pre-committed quantities among lower and upper income groups. Piggot and Marsh (2004) found the evidence of pre-committed demand for meat products in U.S. population using GAIDS model. Pre-commitments were larger for beef products compare to pork and poultry products. Pre-committed demand accounts for 85.7%, 57.4% and 53.1% for beef, pork and poultry, respectively. Tonsor and Marsh (2007) estimated pre-committed beef, pork, poultry and fish demand by U.S. and Japanese households employing the GAIDS model. U.S. consumers had significant pre-committed demand for beef and pork. Japanese consumers on the other hand had significant pre-committed demand for beef and fish but no pre-committed consumption for pork. Pre-committed demand for poultry was not significant in either consumption group. U.S. pre-committed consumptions were estimated as 74% and 73% of average consumption of beef and pork respectively. Conversely, pre-committed consumptions for Japanese households were 67% and 60% of average consumption of beef and fish. These finding suggests that beef is more of a staple item for U.S. households whereas fish is more of a staple in Japan. Rowland et. al. (2017) conducted an empirical analysis on pre-committed demand for oil, natural gas and coal at aggregate level in U.S. using the generalized AIDS model. The pre-committed consumption accounts for 87% of average oil consumption, while pre-commitment levels are 60% and 69% for natural gas and coal respectively. Most of the elasticity estimates associated with the GAIDS specification were larger in absolute value than that of AIDS specification. All own price elasticities were more elastic in the GAIDS model due to presence of pre-commitment levels in the consumption of energy commodities. Based on elasticity estimates, an increase in price of 44.9% is necessary to decrease 7.9% oil consumption if demand system with pre-commitments is appropriate. This is due to very small amount of discretionary demand, only 13% of average oil consumption. On the contrary, if a demand system without pre-commitments is appropriate, only 10.5% price increase could accomplish the same amount decrease in oil consumption.

3.2.2 Food demand estimation in Bangladesh

Several attempts have been made to estimate food demand in Bangladesh. In earlier studies (Alamgir and Berlage 1973; Mahmud 1979), the estimation of food demand focused on only food grains, especially rice and wheat using regression models like semi-log and/or inverse types. Subsequently in the 1980s and later, a larger basket of food items including all important household items like rice, wheat, pulses, fruits and vegetables, fish, meat, egg, milk, edible oils, spices etc. was incorporated in the demand system mostly utilizing the AIDS model (Chowdhury 1982, Ahmed and Shams 1994; Shahabuddin and Zohir 1995; Goletti 1993; Mullah 2005; Murshid et al. 2008; Huq and Arshad 2010, Ganesh-Kumar et al. 2012). Besides, few studies concentrate on estimating demand for specific food items like fish (Ali 2002), meat (Wadud 2006), dairy products (Hannan et al. 2010) and potato (Sabur 1983; Huq et al. 2004). Most of the studies used survey data or single volume of household income and expenditure survey (HIES) data conducted by Bangladesh Bureau of Statistics (BBS). However, none of the studies consider pre-committed demand factor in estimating consumer demand.

In previous demand studies in Bangladesh, Chowdhury (1982) applied the Frisch (1959) method for estimating elasticities of demand under condition of want independence with methodological advantage of it over little availability of price data. In contrary, Bouis (1989) estimated food demand elasticities of Bangladesh using 1973/74 Household Expenditure Survey data assuming marginal utility of consumption of any food depends on the level of consumption of all other foods. Pitt (1983) and Goletti (1993) used Tobit method to estimate the food demand system in Bangladesh. On the other hand, Ahmed and Shams (1994) calculated consumers demand using almost ideal demand system (AIDS) based on household consumption and nutrition survey data conducted by the International Food Policy Research Institute (IFPRI) over the period from September 1991 to November 1992 in Bangladesh. Furthermore, Mullah (2005) studied consumer demand behavior in Bangladesh by using the AIDS model for the HIES 2000 data. He estimated the expenditure elasticity for different food and non-food items. More recently, Huq and Arshad (2010) estimated price and income elasticity of demand for different food items in Bangladesh employing the linear approximate AIDS (LA-AIDS) model with a corrected Stone price index using HIES data during the years 1983/84, 1988/89, 1991/92, 1995/96, 2000, and 2005/06. The most recent attempt to study demand elasticities for food items in Bangladesh was made by Ganesh-Kumar et al. 2012. In this study, household direct demand for 13 food items has been modeled using the quadratic almost ideal demand system (QAIDS) specification, whose parameters are estimated using the Household Income and Expenditure Survey, 2005.

3.3 Methods

3.3.1 The generalized EASI demand model

Lewbel and Pendakur (2009) specified the following cost function to define the EASI demand system:

(1) $$\ln C\left(p,u,\varepsilon\right)=u+\sum_{j=1}^{J}m_j\left(u\right)\ln p_j+\sum_{j=1}^{J}\sum_{k=1}^{J}\alpha_{jk}\ln p_j\ln p_k+\sum_{j=1}^{J}\varepsilon_j\ln p_j$$

where *C* represents cost, *u* is utility, $m_j\left(u\right)$ is a general function of *u*, p_j expresses the j^{th} product's price, ε_j reflects unobserved preference heterogeneity, and α_{jk} are parameters.

Using the Shephard's Lemma $\left(i.e., \frac{\partial \ln C}{\partial \ln p_i}=w_i\right)$ and the cost function in (1), Lewbel and Pendakur (2009) derive a linear approximate EASI demand specification that satisfies the restrictions stemming from consumer theory:

(2) $$w_i\left(p,u,\varepsilon\right)=m_i\left(u\right)+\sum_{i=1}^{J}\alpha_{ik}\ln p_k+\varepsilon_i$$

To incorporate *pre-committed demand* into the EASI system, we follow Bollino (1987) to generalize the EASI cost function in (1) via the inclusion of overhead costs as follows:

(3) $$\ln\left(C-t'p\right)=u+\sum_{j=1}^{J}m_j\left(u\right)\ln p_j+\sum_{j=1}^{J}\sum_{k=1}^{J}\alpha_{jk}\ln p_j\ln p_k+\sum_{j=1}^{J}\varepsilon_j\ln p_j$$

where t_j is a parameter representing pre-committed quantity of the j^{th} product.

The GEASI model is derived through the application of the Sheppard's Lemma to this more general cost function in (3). More specifically, differentiating both sides of the cost function with respect to $\ln p_i$ generates the following functional relationship:

(4) $$\frac{\partial \ln\left(C - t' p\right)}{\partial \ln p_i} = m_i\left(u\right) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k + \varepsilon_i$$

Further simplification of the left hand side of the equation (4) yields:

(5) $$\frac{\partial \ln\left(C - t' p\right)}{\partial \ln p_i} = \frac{\partial \ln\left(C - t' p\right)}{\partial p_i} \frac{\partial p_i}{\partial \ln p_i} = \left(\frac{1}{\left(C - t' p\right)} \frac{\partial\left(C - t' p\right)}{\partial p_i} \right) p_i = \left(\frac{\left(\partial C / \partial p_i\right) - t_i}{C - t' p} \right) p_i$$

Substituting (5) into (4) results in:

(6) $$\left(\frac{\left(\partial C / \partial p_i\right) - t_i}{C - t' p} \right) p_i = m_i\left(u\right) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k + \varepsilon_i$$

Rearranging (6) yields the following expression for $\frac{\partial C}{\partial p_i}$:

(7) $$\left(\frac{\partial C}{\partial p_i} - t_i \right) p_i = \left(C - t' p\right) \left(m_i\left(u\right) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k \right)$$

$$\frac{\partial C}{\partial p_i} p_i - t_i p_i = \left(C - t' p\right) \left(m_i\left(u\right) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k \right)$$

$$\frac{\partial C}{\partial p_i} p_i = t_i p_i + \left(C - t' p\right) \left(m_i\left(u\right) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k \right)$$

$$\frac{\partial C}{\partial p_i} = t_i + \frac{1}{p_i} \left(C - t' p\right) \left(m_i\left(u\right) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k \right)$$

Next, both sides of (7) are multiplied by $\left(\frac{p_i}{C}\right)$ to generate Hicksian budget share equations since

$w_i = \left(\frac{\partial C}{\partial p_i}\right)\left(\frac{p_i}{C}\right) = \left(\frac{q_i p_i}{C}\right)$:

$$w_i = \frac{p_i}{C}\left(t_i + \frac{1}{p_i}(C - t'p)\left(m_i(u) + \sum_{i=1}^{J}\alpha_{ik}\ln p_k\right)\right)$$

(8) $$= \frac{t_i p_i}{C} + \left(\frac{C - t'p}{C}\right)\left(m_i(u) + \sum_{i=1}^{J}\alpha_{ik}\ln p_k\right)$$

$$= \frac{t_i p_i}{C} + \left(1 - \frac{t'p}{C}\right)\left(m_i(u) + \sum_{i=1}^{J}\alpha_{ik}\ln p_k\right)$$

Finally, the implicit GEASI Marshallian demand system is obtained by: (*i*) substituting consumer total expenditure *X* for *C* given a utility maximizing consumer, and (*ii*) replacing $m_i(u)$ with a particular function offered by Lewbel and Pendakur (2009) as shown below:

(9) $$w_i = \frac{t_i p_i}{X} + \left(1 - \frac{t'p}{X}\right)\left(\sum_{r=0}^{L}\beta_{ir}\left(\ln(X - t'p) - w'\ln p\right)^r + \sum_{i=1}^{J}\alpha_{ik}\ln p_k\right) + \varepsilon_i$$

where w_i is the budget share of commodity *i*

t_i is a parameter representing pre-committed quantity of commodity *i*

X is the total expenditure

r denotes the order of the polynomial function of real income that provides a flexible representation of Engel curves

α_{ik}, β_{ir} are parameters

where $m_i(u)$ is replaced by $\sum_{r=1}^{L}\beta_{ir}y^r$ with $y = \ln(X - t'p) - w'\ln p$ and *r* denotes the order of the polynomial function of real income that provides a flexible representation of Engel curves. Note that the system in (9) is subject to the theoretical restrictions of adding-up $\left(\sum_{i=1}^{J}\beta_{i0} = 1;\ \sum_{i=1}^{J}\beta_{ir} = 0, \forall r = 1,\ldots,L; \sum_{i=1}^{J}\alpha_{ik} = 0, \forall k = 1,\ldots,J\right)$

and symmetry $\left(\alpha_{ik}=\alpha_{ki}, \forall i, k=1,\ldots,J\right)$. Importantly, the EASI model is nested in the GEASI specification and can be obtained via the joint restriction of $t_i = 0, \forall i = 1,\ldots,J$ on the GEASI model.

3.3.2 Two- step estimation procedure for a censored GEASI demand model

Because some households did not consume some commodity, the dependent variable or budget share could have a zero value for some observations. Therefore, econometric issue arises as we are dealing with zero consumption in our data set. These zero consumptions could be due to household inventory or non-preference. However, since data were collected during two-week period, it is more possible to have zero consumptions on certain commodity due to shorter survey period. Demand estimation by traditional GEASI model without addressing the demand censoring would result in biased and inconsistent estimates of economic effect. Thus, we adopted two-step estimation procedure of Shonkwiler and Yen (1999) described as below:

Consider the following system of demand equations with limited dependent variables or left-censored variables:

$$(10) \qquad w_{iht}^{*} = f(x_{iht}, \delta_i) + \varepsilon_{iht}, \qquad q_{iht}^{*} = z_{iht}'\theta_i + \nu_{iht}$$

$$q_{iht} = \begin{cases} 1 \ if \ q_{iht}^{*} > 0 \\ 0 \ if \ q_{iht}^{*} \leq 0 \end{cases} \qquad w_{iht} = q_{iht} w_{iht}^{*}$$

(i = 1, 2,….,N ; h = 1,2,…..,H ; t = 1, 2,…., T)

Where,

w_{iht} and q_{iht} are observed budget share and consumption of commodity *i* for household *h* in year *t* respectively,

w_{iht}^{*} and q_{iht}^{*} are corresponding latent variables,

x_{iht} and z_{iht} are vectors of exogenous variables,

δ_i and θ_i are vectors of parameters and,

ε_{iht} and ν_{iht} are random errors.

Assume $[\varepsilon_{iht}, \nu_{iht}]'$ is distributed as bivariate normal with cov $(\varepsilon_{iht}, \nu_{iht})$ = ∂_i for each i. Then, the conditional mean of w_{iht} takes the following functional form:

$$(11) \quad E(w_{iht}/x_{iht}\ , z_{iht}; \nu_{iht} > - z'_{iht}\theta_i) = \text{ʄ}\,(x_{iht}, \delta_i) + \partial_i \frac{\emptyset(z'_{iht}\theta_i)}{\Psi(z'_{iht}\theta_i)}$$

Since $(w_{iht}/x_{iht}\ , z_{iht}; \nu_{iht} \leq - z'_{iht}\theta_i)$= 0, given that w_{iht} is censored, the unconditional mean of w_{iht} is

$$(12) \quad E(w_{iht}/x_{iht}\ , z_{iht}) = \Psi(z'_{iht}\theta_{iht})\,\text{ʄ}\,(x_{iht}, \delta_i) + \partial_{iht}\emptyset(z'_{iht}\theta_i)$$

Based on equation (12) for each i, the system of equation (10) can be written as

$$(13) \quad w_{iht} = \Psi(z'_{iht}\theta_i)\,\text{ʄ}\,(x_{iht}, \delta_i) + \partial_i\emptyset(z'_{iht}\theta_i) + \xi_{iht}$$

Replacing $\text{ʄ}\,(x_{iht}, \delta_{iht})$ with GEASI specification, we derived the following censored GEASI demand model for analysis:

$$(14) \quad w_{iht} = \Psi(z'_{iht}\theta_i)\left\{\frac{t_i p_i}{X} + \left(1 - \frac{t'p}{X}\right)\left(\sum_{r=0}^{L} \beta_{ir}\,(ln(X - t'p) - w'lnp)^{\,r} + \sum_{i=1}^{J} \alpha_{ik}\, lnp_k\right)\right\} + \xi_{iht}$$

Following Shonkwiler and Yen (1999), the equation (14) is estimated by a two-step procedure: i) estimation of θ_i using the binary outcome $q_{iht} = 1$ and $q_{iht} = 0$ through ML probit model, where q_{iht} is regressed on indicator variables like household head's age, gender, income, education, year, region, and division ii) estimation of $\Psi\left(z'_{iht}\widehat{\theta_i}\right)$ based on $\widehat{\theta_i}$ and also the equation (14).

3.3.3 Elasticity formulas for the GEASI model

We follow Hovannisyan and Shanoyan (2018) to derive the expenditure, Hicksian, and Marshallian elasticity formulas for the GEASI model using the expenditure share equations in (14). Specifically, the GEASI expenditure elasticity formula is provided below:

$$E=\left(diag\left(W\right)\right)^{-1}\left[\left[I_J+\left(\left(\frac{X-t'p}{X}\right)*B\right)\left(\ln p\right)'\right]^{-1}\left[\frac{t\circ p}{X}+\frac{t'p}{X}A+B\right]\right]+1_J, \qquad (15)$$

where E is the $(J$ x 1) expenditure elasticity vector with e_i denoting its i^{th} element, W represents the (J x 1) vector of observed commodity budget shares, $\ln p$ is the $(J$ x 1) vector of log prices, B is a (J x 1) vector with its i^{th} element represented by $\sum_{l=1}^{L}\left(\beta_{il}+\beta_{il}^{u}Urb_{rt}\right)ly^{l-1}$ $A=\left(\sum_{r=0}^{L}\beta_{ir}\left(\ln\left(X-t'p\right)-w'\ln p\right)^{r}+\sum_{k=1}^{J}\alpha_{ik}\ln p_k\right)$, 1_J is a $(J$ x 1) vector of ones, and $\circ$ is the Hadamard-Schur product with $t\circ p=\left[t_1p_1,...,t_Np_N\right]$. Equation **Error! Reference source not found.** accounts for the fact that expenditure shares $\left(w_i\right)$ also appear on the right side of the GEASI system through real expenditure $\left(y_{rt}\right)$ and its polynomials.

Hicksian elasticities for the GEASI model are:

$$e_{ij}^{H}=\frac{1}{w_i}\left[\frac{t_ip_i}{X}-\frac{t_ip_i}{X}A+\left[1-\frac{t'p}{X}\right]\alpha_{ii}\right]+w_j-\delta_{ij},\ \forall i,j=1,...,J, \qquad (16)$$

where δ_{ij} is the Kronecker delta equaling 1 if $i=j$, and 0 otherwise.

Using the Hicksian $\left(e_{ij}^{H}\right)$ and expenditure elasticity estimates $\left(e_i\right)$, the Marshallian price elasticities $\left(e_{ij}^{M}\right)$ can be obtained from the Slutsky equation: $e_{ij}^{M}=e_{ij}^{H}\frac{\alpha_{ij}}{w_i}-w_j\,\mathrm{e}_i$.

(17) $$e_{ij}^{M} = \left[\left[\frac{t_i p_i}{X} - \frac{t_i p_i}{X} A + \left[1 - \frac{t' p}{X}\right]\alpha_{ii}\right] + w_j - \delta_{ij}\right]\frac{\alpha_{ij}}{w_i^2} - w_j \, \mathrm{e}_i \, .$$

3.4 Data

3.4.1 Data source

The source of data for this study is the Bangladesh Bureau of Statistics (BBS), centralized official bureau under the ministry of planning in Bangladesh for assembling statistics on demographics, agriculture, the economy, and other facts about the country and disseminating the information. BBS has been conducting the Household Income and Expenditure Survey (HIES) on a regular basis as the core survey to provide with very important data like income, expenditure, consumption and poverty situation both in rural and urban areas representing the whole country. After the independence in 1971, BBS has successfully completed 16 rounds of HIES: 1973-74, 1974-75, 1975-76, 1976-77, 1977-78, 1978-79, 1981-82, 1983-84, 1985-86, 1988-89, 1991-92, 1995-96, 2000, 2005, 2010 and 2016. The present demand analysis is based on secondary data extracted from Household Income and Expenditure Survey (HIES) during the years 2000, 2005, 2010, and 2016. The reason behind choosing the last 4 round HIES data from 2000 to 2016 is that the scope of the survey was broadened in the year 2000 and accordingly it was renamed as Household Income and Expenditure Survey (HIES) which was named as Household Expenditure Survey (HES) in first 12 rounds survey after the independence.

3.4.2 Data description

HIES covers wide range of socio-economic information at the household level on following 9 modules: i) Household information, ii) Education, iii) Health, iv) Economic activities and wage employment, v) Non-agricultural enterprises, vi) Housing, vii) Agricultural enterprises, viii) Other income and assets, and ix) Consumption. The HIES 2000, 2005, 2010, and 2016 data on household-level consumption is quite detailed. The consumption of food items in quantity and expenditure was divided into 17 major food categories and collected all consumption information for two-week period. The major categories were cereals, pulses, fish, eggs, meat, vegetables, milk and dairy products, sweets, oil and fats, fruits, drinks, sugar and molasses, tobacco and related items, spices, betel leaves, and betel nuts. In the cereal category, there were sub-categories of rice, wheat, and processed rice and wheat products. Again, rice was sub-categorized according to fine rice, medium rice, coarse rice, beaten flat rice, and popped (puffed) rice. Rice is a staple food in Bangladesh where per capita consumption is 367.19 gm per day which is the highest in the world (BBS 2017b). Rice constitutes 62% budget share of total food expenditure of the poorest people in Bangladesh (Sulaiman et al. 2009). Besides rice, egg, vegetables and oil are the most important food items in the basket of both poor and rich households for which a significant portion of pre-committed demand is expected to be present.

3.4.3 Sample size

The sample size in HIES 2000, 2005, 2010, and 2016 were 7440, 10,080, 12240, and 46080, respectively. Although the total number of households included in the last four round HIES survey was 75840, we dropped 14458 observation due to have extreme lower or higher values which were not sensible in the context of Bangladesh and finally, we have 61382 observation for analysis.

3.4.4 Data summary

Table 3.1 presents the descriptive statistics for average agricultural commodity prices, per capita annual food consumption, budget share of different food items, per capita annual income and shares of food and non-food expenditure of Bangladeshi households during the survey period from 2000 to 2016. We concentrate our analysis on 14 major food items- beef, chicken, mutton, fish, rice, wheat, pulse, fruit, vegetables, onion, milk, egg, sugar and oil that are most commonly consumed by the households of Bangladesh. Among all food commodity, mutton appears to be the most expensive (372.09 Tk./kg) item in Bangladesh followed by beef (289.31 Tk./kg), chicken (146.03 Tk./kg) and fish (122.21 Tk./kg). On the contrary, egg (6.72 Tk./piece) is found to be the cheapest food item whereas vegetables (17.58 Tk./kg), onion (24.78 Tk./kg) and wheat (25.24 Tk./kg) are ranked as second, third and fourth cheapest food items respectively. Overall, meats are the most expensive food item in Bangladesh compare to other food items. Table 3.1 also summarizes per capita annual food consumption in Bangladesh. Rice is a major crop and staple food as well and thus, extensively consumed in the country. The per capita annual consumption of rice is very high (173.78 kg) compare to wheat (4.79 kg), the other vital staple food in the world. Vegetable is another important food item for Bangladeshi people having the second largest per capita annual consumption (97.10 kg). Besides, fish and egg are also frequently consumed and more popular food items than meat in Bangladesh due to less price. The reason behind that might be the increasing trend of commercial fish and poultry farming in Bangladesh which causes higher production and lower prices compare to meat categories. It is also apparent from the Table 3.1 that the household spend most of the food budget purchasing rice (28%), followed by fish (11.65%), vegetables (8.20%), oil (3.20%), beef (2.65%) etc. Per capita annual income is estimated to be 44383 Tk. on average. Finally, Table 3.1 also represents the share of food and non-food items of households. Bangladesh, being a developing country, has a significant amount of food budget, more than 57% of total expenditure whereas the budget share of non-food item is around 43%.

The comparisons of food price, per capita consumption, budget share, income, and share of expenditure among different years are depicted in Table 3.2. The prices of all food items were continuously increasing over the period from 2000 to 2016 but following the global trend there were a sharp increase in prices of most of the commodities from 2005 to 2010. It is notable, the prices of meat specially beef and mutton prices were increased remarkably compare to other food items. For example, the price of beef was increased to 412 Tk. /kg in the year 2016 from 70 Tk./kg in 2000, an increase of 586%. On the other hand, mutton price was increased by 482%, from 108 Tk./kg in 2000 to 519 Tk./kg in 2016. Apart of these, the prices of other food items were augmented around a range between 200% to 300% from the year 2000 to 2016. Interestingly, the per capita annual food consumption increased significantly for chicken (from 6.39 kg to 1.39 kg), fish (from 16.98 kg to 24.48 kg), wheat (from 0.77 kg to 7.40 kg), vegetables (from 86.5 kg to 99.90 kg), egg (from 29 pieces to 51 pieces), and oil (from 4.30 liter to 10.93 liter). On the contrary, consumption of rice, fruits and milk decreased significantly. Nevertheless, the consumption of rice was gradually decreasing over the periods mostly due to change in food preferences and health consciousness. Moreover, fruits and milk consumption were also shrunk over the period. The changes in food consumption are reflected in the changes of budget share in Table 3.2. The per capita annual income is rising throughout the period from 17784 Tk. in 2000 to 57133 Tk. in 2016. However, the income rose remarkably from 2005 to 2010, became almost double due to expansion of economic activities in Bangladesh. Interestingly, the annual budget for food is decreasing and the budget for non-food is increasing indicating the rising income of the households.

Table 3.1 Descriptive Statistics for Food Price, Consumption, Budget Share, Income, and Share of Expenditure

Variable	Mean	Std.	Variable	Mean	Std.
Average food price			**Budget share (%)**		
Beef (Tk./kg)	289.31	147.10	Beef	3.07	7.11
Chicken (Tk./kg)	146.03	56.39	Chicken	3.22	4.61
Mutton (Tk./kg)	372.09	181.95	Mutton	0.37	2.42
Fish (Tk./kg)	122.21	65.70	Fish	13.54	7.94
Rice (Tk./kg)	28.84	10.30	Rice	27.98	13.24
Wheat (Tk./kg)	25.24	6.99	Wheat	0.78	2.18
Pulse (Tk./kg)	96.98	35.97	Pulse	1.70	1.70
Fruit (Tk./kg)	60.86	62.07	Fruit	2.83	3.92
Vegetable (Tk./kg)	17.58	8.93	Vegetable	9.14	4.11
Onion (Tk./kg)	24.78	9.37	Onion	1.46	0.88
Milk (Tk./liter)	41.62	19.53	Milk	1.95	3.42
Eggs (Tk./piece)	6.72	2.47	Eggs	1.45	1.72
Sugar (Tk./kg)	57.29	17.50	Sugar	0.69	1.06
Oil (Tk./liter)	81.86	23.62	Oil	3.84	2.37
Per capita annual food consumption			**Per capita annual income (Tk.)**	44383.04	88661.85
Beef (kg)	3.09	9.21	**Share of expenditure (%)**		
Chicken (kg)	4.95	8.07	Food	57.06	15.60
Mutton (kg)	0.27	2.19	Non-food	42.93	15.60
Fish (kg)	22.10	15.23			
Rice (kg)	164.92	61.97			
Wheat (kg)	6.12	15.65			
Pulse (kg)	3.58	4.07			
Fruit (kg)	15.29	26.96			
Vegetable (kg)	98.82	47.95			
Onion (kg)	10.89	7.43			
Milk (liter)	11.30	21.45			
Eggs (piece)	42.97	58.04			
Sugar (kg)	2.70	4.62			
Oil (liter)	8.81	6.76			

Source: Household Income and Expenditure Survey (2000, 2005, 2010, and 2016), Bangladesh Bureau of Statistics

Table 3.2 Comparison of Food Price, Consumption, Budget Share, Income, and Share of Expenditure among Different Years

Variable	Year							
	2000		2005		2010		2016	
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
Average food price								
Beef (Tk./kg)	70.39	8.80	99.28	9.82	238.50	14.07	412.72	54.80
Chicken (Tk./kg)	84.23	14.81	89.42	17.93	151.84	28.51	174.54	53.95
Mutton (Tk./kg)	108.74	19.14	138.72	20.86	318.32	21.83	519.35	86.58
Fish (Tk./kg)	52.76	20.07	59.94	19.16	115.72	35.33	158.51	62.49
Rice (Tk./kg)	12.52	1.82	17.28	1.78	32.91	4.26	34.45	7.43
Wheat (Tk./kg)	15.31	2.81	19.29	3.19	25.41	4.42	29.14	5.71
Pulse (Tk./kg)	39.58	2.08	47.23	3.93	106.42	10.83	121.16	17.30
Fruit (Tk./kg)	23.54	23.94	28.76	23.81	52.60	30.49	81.67	74.41
Vegetable (Tk./kg)	7.82	2.03	8.34	2.48	14.80	4.36	23.50	7.48
Onion (Tk./kg)	14.37	4.47	20.29	9.33	27.20	9.13	27.55	8.05
Milk (Tk./liter)	17.53	4.98	19.90	5.57	37.07	8.40	55.08	14.80
Eggs (Tk./piece)	3.00	0.49	3.44	0.46	6.29	0.68	8.68	1.01
Sugar (Tk./kg)	33.69	4.88	37.77	4.69	53.90	5.19	69.55	12.75
Oil (Tk./liter)	40.75	5.08	53.42	5.63	90.24	9.89	96.44	12.10
Per capita annual food consumption								
Beef (kg)	3.70	7.82	3.46	9.74	2.77	9.02	2.96	9.38
Chicken (kg)	1.79	4.57	2.95	6.60	4.55	8.22	6.39	8.65
Mutton (kg)	0.23	1.93	0.31	2.90	0.27	1.94	0.27	2.08
Fish (kg)	16.98	11.66	18.72	12.77	21.59	14.62	24.43	16.30
Rice (kg)	186.02	60.49	184.72	60.29	172.89	61.58	151.48	59.50
Wheat (kg)	0.77	4.37	0.27	2.22	10.71	20.91	7.40	16.49
Pulse (kg)	3.16	3.72	3.72	4.20	2.94	3.58	3.86	4.23
Fruit (kg)	12.20	20.74	14.95	27.20	19.27	33.57	14.65	25.23
Vegetable (kg)	86.50	39.57	98.03	44.66	103.98	47.10	99.90	50.37
Onion (kg)	7.11	4.81	8.12	5.75	9.70	6.16	12.98	8.05
Milk (liter)	11.64	20.60	13.35	24.05	13.03	23.51	9.98	19.87
Eggs (piece)	28.65	47.25	29.37	48.54	40.97	57.64	50.92	61.44
Sugar (kg)	2.10	3.68	2.78	4.65	3.38	5.27	2.56	4.52
Oil (liter)	4.30	4.70	5.76	5.45	8.24	5.92	10.93	6.90
Budget share (%)								
Beef	1.52	2.66	2.83	6.00	2.63	6.40	3.63	8.19
Chicken	0.78	1.65	2.15	3.97	3.00	4.53	4.16	4.96
Mutton	0.13	0.93	0.33	2.35	0.34	2.10	0.44	2.74
Fish	6.04	3.08	11.56	6.07	13.07	6.80	15.94	8.33
Rice	18.72	6.83	38.14	14.14	34.33	13.45	24.66	10.90

Wheat	0.06	0.31	0.04	0.36	1.51	3.19	0.89	2.19
Pulse	0.83	0.89	1.77	1.73	1.59	1.73	1.92	1.75
Fruit	1.30	1.74	2.78	3.81	3.31	4.30	3.01	4.08
Vegetable	5.00	1.72	8.93	3.17	8.54	3.23	10.32	4.37
Onion	0.73	0.39	1.67	1.03	1.43	0.79	1.57	0.87
Milk	1.19	1.90	2.34	3.74	2.18	3.66	1.92	3.47
Eggs	0.56	0.83	1.00	1.40	1.29	1.58	1.83	1.87
Sugar	0.40	0.61	0.90	1.25	0.83	1.10	0.64	1.04
Oil	1.15	1.04	3.05	2.30	4.01	2.23	4.60	2.15
Per capita annual income (Tk.)	17784	46580.78	22625	42975.66	43350	75133.26	57133	106083
Share of expenditure (%)								
Food	72.92	11.90	58.22	14.53	60.16	13.47	52.15	14.65
Non-food	27.08	11.90	41.78	14.53	39.84	13.47	47.85	14.65

Source: Household Income and Expenditure Survey (2000, 2005, 2010, and 2016), Bangladesh Bureau of Statistics

3.5 Results and Discussion

3.5.1 Estimation and result from the GEASI model

The GEASI demand equations are estimated through the Full Information Maximum Likelihood (FIML) procedure with allowance being made for contemporaneous correlation across the stochastic terms of the system. Table 3.3 reports the parameter estimates from the GEASI system of 14 demand equations with a quintic Engle curve structure. Most of the income and price coefficient are found to be statistically significant. Importantly, pre-committed demand coefficients are estimated to be positive and also statistically significant for rice, pulse, vegetables and onion indicating the evidence of pre-committed consumption for those food items. These finding suggest that rice, pulse, vegetables and onion are more of staple items for Bangladeshi households. Table 3.4 illustrates that the annual per capita pre-committed consumption level for rice, pulse, vegetables and onion are 26.72 kg, 1.15 kg, 9.61 kg and 2.38 kg, respectively. Furthermore, it is also surprising to find that the pre-committed demand is absent for other important food commodities like oil, fish, egg etc. in Bangladeshi households. Since this is the first study in Bangladesh that estimates the pre-committed demand, there are no articles to compare results of this study. Nevertheless, the literature of food demand estimation includes the evidence of pre-committed demand in case of two developing countries- China and Russia. Interestingly, findings are similar to this study such as Hovhannisyan and Gould (2011) explored the presence of positive significant pre-committed quantities for vegetables, rice, other grains and fat/oil products in China while Hovhannisyan and Shanoyan (2018) findings supported the presence of pre-committed demand for cereals, eggs and fat/oils in Russia. It is also noteworthy that the evidence of pre-committed food items is not similar between developing and developed countries. For example, Piggott and Marsh (2004) estimated pre-committed demand for beef, pork and poultry in U.S. households. Tonsor and Marsh (2007) also found the presence of pre-committed demand for beef and pork in U.S. and also for fish and beef in Japan. These suggest developing countries consumers' have pre-committed demand for relatively less expensive and essential food items whereas developed countries consumers' have pre-committed demand for expensive and protein enriched food items.

To compare the percentage of pre-committed consumption may be more insightful since this provides more information regarding the sensitivity of total consumption to changes in factors affecting pre-committed demand. Table 3.4 indicates pre-commitment accounts for 16.20%, 32.04%, 9.73% and 21.82% of total rice, pulse, vegetables and onion consumption, respectively, indicating these portions of demand are perfectly inelastic due to change in economic factors like price and expenditure. This implies that factors other than price and expenditure significantly impact the demand for these products on the pre-committed portions. Conversely, the demand of all food items except rice, pulse, vegetables and onion are significantly affected by price and expenditure. It is also interesting that the proportion of pulse consumption estimated to be pre-committed is higher than that of rice, vegetables and onion. This suggests that pulse demand is relatively more influenced by non-economic factors, though this research cannot explicitly identify exactly what underlies and affects this pre-committed demand. Besides, the percentages of pre-committed demand in Russia are as lower as Bangladesh estimated as 17.6%, 18.4%, and 27.8% of cereal, eggs, and fat/oils demands, respectively. But the proportion of pre-committed demand is higher in case of developed countries. Tonsor and Marsh (2007) estimated pre-committed consumptions as 74% and 73% of average consumption of beef and pork, respectively in the United States. On the other hand, pre-committed consumptions for Japanese households were 67% and 60% of average consumption of beef and fish, respectively.

The findings of this study provide evidence that factors besides price and expenditure contributes significantly on demand of rice, pulse, vegetables and onion but identifying those non-economic factors are beyond the scope of this study. However, the cultural factors like food habit and lifestyle may be those non-economic factors for which pre-committed demand arises in Bangladesh. Although there are few previous studies which estimate the pre-committed demand both in developing and developed countries but the factors affecting pre-committed demand are also unexplored in those studies. However, Piggott and Marsh (2004) suggest that food safety impacts may influence these pre-committed quantities, while Tonsor and Marsh (2007) points out the factors like generic advertising, health concerns, differences in underlying consumer perceptions, etc. may affect the pre-committed demand. Overall, the findings of this research and other related researches provide the documentation that consumers form different countries have heterogeneous responses to pre-committed demand in terms of both choice and magnitude. However, the households in developing countries have shown pre-committed demand mainly for cereals and vegetables at a lower proportion of average consumption whereas in developed countries the evidence pre-committed demand is found on meat and fish at a higher percentage of average consumption.

The Marshallian and Hicksian own-price and cross-price elasticity estimates from the GEASI model are presented in Table 3.5 and 3.6, respectively. The diagonal elements of the Tables indicate own-price elasticity while the off-diagonal elements are cross-price elasticity evaluated at sample mean values. All the Marshallian and Hicksian own-price elasticity estimates are negative and therefore, consistent with the theory of demand indicating demand decreases with increase in price and vice versa. Moreover, these elasticity estimates are also statistically significant. The Marshallian own-price elasticities of chicken (-0.51), fish (-0.61), rice (-0.91), vegetables (-0.81), onion (-0.78), egg (-0.61) and oil (-0.82) appear to be inelastic ranging between -0.51 to -0.91 in terms of elasticity estimates. On the contrary, beef (-1.19), mutton (-2.06), wheat (-2.06), fruit (-1.34), milk (-1.48) and sugar (-1.11) are own-price elastic having an elasticity range between -1.1 to -2.1, shown in Table 3.5. The own-price elasticity of pulse is -1.0, unitary elastic. Table 3.7 denotes that the Hicksian own-price elasticities seem to be more inelastic than the Marshallian elasticities having a range between -0.45 to -0.79. For example, the Marshallian own-price elasticity of rice is -0.91 whereas it is -0.52 in the Hicksian estimate. The change in the price of rice does not lead to change in the consumption of the households significantly because rice is a staple food in Bangladesh and also there is no close substitute of rice that are commonly consumed in the country. We can realize the scenario from Table 3.1 where the annual per capita consumption of rice is 164.92 kg, the consumption of wheat is only 6.12 kg. Other demand studies based on Bangladesh, found a wide range of own price elasticity for rice ranging from -0.11 to -1.32 depending on the types and time of data and methods of estimation. For example, the estimated own price elasticities of Alamgir and Berlage (1973), Mahmud (1979), Karim (1983), Rahman (1989), Talukder (1990), Ahmed and Shams (1994), Ahmed (1997), Dorosh (1999), and Begum and D'Haese (2010) were -0.29, -0.39, -0.39, -1.18, -0.73, -0.12, -0.15, -0.50, and -0.11, respectively. The Hicksian own-price elasticity for fish (-0.07), vegetables (-0.70), onion (-0.76), egg (-0.59) and oil (-0.79) are also more inelastic compare to Marshallian elasticities. Like the Marshallian, the Hicksian own-price elasticities for beef (-1.03), mutton (-2.06), wheat (-2.05), fruit (-1.25), milk (-1.42) and sugar (-1.09) are also own-price elastic but slightly lower in magnitude. Furthermore, pulse has unitary own-price elasticity same as the Marshallian. Overall, the magnitude of the Hicksian own-price elasticity estimates are less than that of the Marshallian elasticity.

Many of the cross-price elasticity estimates are significant and consistent with expectations. In case of Marshallian cross-price elasticities, 150 elasticity estimates out of 182 are found to be significant. Substitution relationship is found between rice and wheat (0.029) in cereal category. Among the animal sourced food category, milk is substitute to beef (0.21), mutton (0.10) and fish (0.17) but complementary to chicken (-0.07) and egg (-0.17). Different meat items are estimated to be complementary to each other although they might be substitutes in household consumption. In fact, some of the cross-price elasticities will be less intuitive than others, when so many cross-price elasticities are estimated (Zhen et al., 2013). On the other hand, there is a complimentary relationship between rice and fish (-0.08) which is consistent with household food habit in Bangladesh. Moreover, fruit and vegetable are also found to be complementary to each other (-0.14). Oil is estimated to be complementary to beef (-0.02), chicken (-0.07), fish (-0.09) and pulse (-0.01) since household uses oil to cook this food items. In contrast, out of 182 Hicksian cross-price elasticities, 145 are statistically significant. In case of Hicksian elasticities, rice is found to be substitute to all food items. Similarly, vegetable is substitute to all food items except milk. Beef and fish are estimated to be substitute to each other while different meat categories are mostly complementary to each other.

Table 3.7 indicates that all expenditure elasticities are positive and significant meaning normal goods i.e. consumption increases with the increase of total expenditure. The expenditure elasticities of beef (3.70), fruit (2.23), milk (2.53) and sugar (1.73) are elastic but elasticities of mutton (0.18), fish (0.82), wheat (0.77), vegetable (0.89), onion (0.87), eggs (0.86), and oil (0.83) are inelastic. In the contrary, the expenditure elasticities of chicken (1.10), rice (0.99), and pulse (1.03) are approximately unitary elastic.

Table 3.3 Parameter Estimates from the GEASI System

Parameter	**Beef**	**Chicke**	**Mutton**	**Fish**	**Rice**	**Wheat**	**Pulse**	**Fruit**	**Vegetable**	**Onion**	**Milk**	**Eggs**	**Sugar**	**Oil**
Pre-committed demand	0.00	0.00	0.00	0.00	**1383.73**	0.00	**212.96**	0.00	**286.66**	**130.15**	0.00	0.00	0.00	10.20
	94.79	*66.65*	*95.41*	*83.17*	*146.37*	*63.55*	*28.14*	*32.38*	*29.44*	*10.76*	*81.94*	*38.35*	*22.27*	*28.72*
Intercept	**-1946.09**	**81.11**	**754.15**	**1762.25**	**4094.80**	**102.65**	**276.84**	**372.03**	**1263.06**	**212.20**	**174.96**	**197.15**	**217.66**	**559.71**
	33.06	*19.22*	*121.48*	*18.27*	*27.37*	*22.45*	*3.70*	*12.12*	*3.67*	*1.54*	*14.61*	*4.97*	*4.31*	*3.42*
Income (β_{i1})	**1122.77**	**40.83**	-40.16	**-337.93**	-33.32	-23.20	7.29	**487.89**	**-139.38**	**-27.13**	**410.93**	**-27.29**	**72.43**	**-86.55**
	31.21	*16.55*	*69.94*	*29.20*	*41.33*	*13.21*	*5.67*	*14.23*	*6.57*	*1.73*	*16.91*	*5.77*	*5.02*	*5.63*
Income (β_{i2})	**202.63**	-17.63	**665.19**	**-50.46**	2.08	**-34.63**	**-20.54**	**-19.64**	**11.98**	**4.47**	**-73.96**	-1.84	**-7.67**	-4.51
	20.84	*12.43*	*53.64*	*23.97*	*31.01*	*12.05*	*4.16*	*10.05*	*5.28*	*1.50*	*11.33*	*4.04*	*2.98*	*4.10*
Income (β_{i3})	26.28	**-33.00**	**622.11**	**-113.55**	**231.77**	5.98	**-17.27**	**-101.56**	**24.57**	**-3.83**	**-111.77**	**-30.22**	**-14.17**	**-10.38**
	14.35	*6.77*	*27.03*	*11.89*	*15.32*	*6.09*	*2.15*	*5.57*	*2.89*	*0.61*	*7.62*	*2.18*	*1.91*	*2.45*
Income (β_{i4})	**-6.87**	**6.92**	**-64.18**	**24.28**	**-52.00**	1.03	**4.61**	**15.50**	**-8.40**	**1.02**	**17.32**	**5.45**	**2.28**	**3.50**
	2.70	*1.82*	*6.96*	*3.69*	*4.44*	*2.20*	*0.78*	*1.40*	*0.88*	*0.28*	*1.77*	*0.70*	*0.47*	*0.61*
Income (β_{i5})	**-2.86**	**1.68**	**-49.48**	**7.50**	**-17.11**	**1.73**	**1.83**	**6.57**	**-1.61**	**0.36**	**7.61**	**2.59**	**0.97**	**1.22**
	1.24	*0.61*	*2.00*	*1.06*	*1.28*	*0.65*	*0.22*	*0.47*	*0.27*	*0.06*	*0.72*	*0.22*	*0.19*	*0.23*
Price (α_{1i}) Beef	-31.20	**-44.79**	3.11	-15.54	**-54.38**	-10.11	**-30.19**	**80.63**	**90.27**	**4.35**	**72.72**	**-26.08**	**-25.67**	**-13.13**
	39.49	*10.37*	*27.23*	*12.88*	*18.57*	*9.11*	*4.99*	*9.68*	*6.52*	*2.01*	*12.81*	*4.88*	*4.53*	*4.55*
Price (α_{2i}) Chicken		**212.11**	7.06	**-116.95**	**78.11**	**-23.85**	**-22.56**	-6.50	**-21.09**	**-10.69**	-0.97	**-15.83**	**4.71**	**-38.76**
		8.40	*12.18*	*7.10*	*10.05*	*4.41*	*2.22*	*4.57*	*2.95*	*0.96*	*5.48*	*2.12*	*1.78*	*2.05*
Price (α_{3i}) Mutton			-51.74	**-142.39**	17.41	**53.09**	**23.95**	**-28.47**	5.43	**9.60**	**27.64**	**39.33**	**-17.34**	**53.32**
			49.69	*17.73*	*25.39*	*11.17*	*4.62*	*10.58*	*5.81*	*1.76*	*11.99*	*4.35*	*3.72*	*3.94*
Price (α_{4i}) Fish				**673.08**	**-326.17**	**-26.64**	**10.01**	**78.71**	**-135.38**	**-21.60**	**121.95**	**-19.19**	**-14.96**	**-64.92**
				14.33	*19.30*	*4.98*	*2.59*	*5.73*	*3.24*	*1.10*	*6.70*	*2.67*	*2.20*	*2.57*
Price (α_{5i}) Rice					**333.50**	**111.55**	-1.60	**-39.92**	**-102.95**	**-7.13**	**-29.27**	-2.60	16.93	6.53
					30.66	*6.52*	*3.44*	*8.20*	*4.02*	*1.26*	*9.57*	*3.52*	*2.69*	*3.52*
Price (α_{6i}) Wheat						**-108.16**	-0.01	**18.13**	-2.21	**-2.72**	**-10.62**	**-16.60**	**10.33**	**7.82**
						6.74	*2.17*	*3.78*	*2.87*	*0.97*	*5.34*	*2.17*	*1.79*	*2.06*
Price (α_{7i}) Pulse							-4.56	2.40	**21.23**	**-3.11**	**38.83**	**-33.54**	**7.07**	**-7.93**
							4.12	*1.98*	*2.47*	*1.14*	*3.19*	*2.59*	*1.86*	*2.23*
Price (α_{8i}) Fruit								**-116.43**	**8.65**	**-1.52**	-1.56	**-7.86**	**6.46**	**7.29**
								6.66	*2.46*	*0.78*	*5.11*	*1.95*	*1.54*	*1.79*
Price(α_{9i}) Vegetable									**226.14**	**2.39**	**-52.53**	**20.49**	**28.05**	**-9.80**
									4.14	*1.13*	*3.93*	*2.49*	*2.05*	*2.26*
Price (α_{10i}) Onion										**45.58**	**5.37**	**-9.33**	-0.76	**-10.42**
										0.99	*1.36*	*1.22*	*0.88*	*1.05*
Price (α_{11i}) Milk											**-118.97**	**-37.97**	**9.89**	**-24.51**
											12.00	*3.20*	*2.66*	*2.93*
Price (α_{12i}) Eggs												**77.90**	1.03	**30.26**
												4.34	*1.95*	*2.34*
Price (α_{13i}) Sugar													**-9.80**	**-15.94**
													3.05	*1.76*
Price (α_{14i}) Oil														**80.21**
														3.32

Note: The italicized numbers are the estimated parameter standard errors. Values in bold identify elasticity estimates that are statistically different from 0 at or below the 0.05 significance level.

Table 3.4 Pre-committed and Discretionary Demand as a Percentage of Per Capita Annual Average Food Consumption

Commodity	**Annual average (kg)**	**Pre-commitment (kg)**	**Pre-commitment (%)**	**Discretionary (%)**
Rice	164.92	26.72	16.20	83.80
Pulse	3.58	1.15	32.04	67.96
Vegetables	98.82	9.61	9.73	90.27
Onion	10.89	2.38	21.82	78.18

Table 3.5 Marshallian Price Elasticity Estimates from the GEASI System

	Beef	Chicken	Mutton	Fish	Rice	Wheat	Pulse	Fruit	Vegetable	Onion	Milk	Eggs	Sugar	Oil
Beef	**-1.187**	**-0.224**	-0.006	**-0.542**	**-1.188**	**-0.052**	**-0.136**	**0.086**	**-0.129**	**-0.045**	**0.102**	**-0.116**	**-0.089**	**-0.172**
	0.095	*0.025*	*0.065*	*0.033*	*0.052*	*0.022*	*0.012*	*0.023*	*0.018*	*0.005*	*0.031*	*0.012*	*0.011*	*0.011*
Chicken	**-0.108**	**-0.513**	0.016	**-0.288**	**0.144**	**-0.056**	**-0.054**	-0.019	**-0.061**	**-0.027**	-0.005	**-0.039**	**0.010**	**-0.095**
	0.024	*0.020*	*0.028*	*0.017*	*0.027*	*0.010*	*0.005*	*0.011*	*0.008*	*0.002*	*0.013*	*0.005*	*0.004*	*0.005*
Mutton	0.098	0.180	**-2.056**	**-2.763**	0.679	**1.096**	**0.510**	**-0.550**	0.217	**0.214**	**0.588**	**0.822**	**-0.347**	**1.135**
	0.559	*0.256*	*1.017*	*0.445*	*0.762*	*0.230*	*0.101*	*0.227*	*0.222*	*0.047*	*0.250*	*0.094*	*0.077*	*0.110*
Fish	-0.001	**-0.055**	**-0.075**	**-0.606**	**-0.104**	**-0.012**	**0.010**	**0.049**	**-0.049**	**-0.008**	**0.070**	**-0.007**	**-0.006**	**-0.025**
	0.007	*0.004*	*0.010*	*0.009*	*0.012*	*0.003*	*0.001*	*0.003*	*0.003*	*0.001*	*0.004*	*0.002*	*0.001*	*0.002*
Rice	**-0.014**	**0.020**	0.005	**-0.082**	**-0.912**	**0.029**	0.000	**-0.010**	**-0.025**	**-0.002**	**-0.007**	-0.001	**0.004**	**0.002**
	0.005	*0.003*	*0.007*	*0.005*	*0.009*	*0.002*	*0.001*	*0.002*	*0.002*	*0.000*	*0.003*	*0.001*	*0.001*	*0.001*
Wheat	-0.090	**-0.224**	**0.521**	**-0.218**	**1.181**	**-2.056**	0.005	**0.187**	0.008	**-0.022**	-0.098	-0.158	0.103	0.088
	0.089	*0.043*	*0.109*	*0.053*	*0.076*	*0.066*	*0.021*	*0.037*	*0.031*	*0.010*	*0.052*	*0.021*	*0.018*	*0.021*
Pulse	**-0.129**	**-0.097**	**0.101**	**0.037**	-0.019	0.000	**-1.020**	0.009	**0.086**	**-0.014**	**0.164**	**-0.143**	**0.030**	**-0.035**
	0.021	*0.009*	*0.020*	*0.011*	*0.016*	*0.009*	*0.018*	*0.008*	*0.011*	*0.005*	*0.014*	*0.011*	*0.008*	*0.010*
Fruit	**0.151**	**-0.069**	**-0.078**	**-0.031**	**-0.580**	**0.033**	**-0.023**	**-1.341**	**-0.135**	**-0.029**	**-0.037**	**-0.044**	0.004	**-0.046**
	0.024	*0.012*	*0.027*	*0.016*	*0.025*	*0.010*	*0.005*	*0.017*	*0.008*	*0.002*	*0.013*	*0.005*	*0.004*	*0.005*
Vegetable	**0.075**	**-0.012**	0.005	**-0.085**	**-0.038**	-0.001	**0.019**	**0.011**	**-0.810**	**0.004**	**-0.038**	**0.018**	**0.023**	-0.002
	0.005	*0.002*	*0.005*	*0.003*	*0.004*	*0.002*	*0.002*	*0.002*	*0.004*	*0.001*	*0.003*	*0.002*	*0.002*	*0.002*
Onion	**0.027**	**-0.046**	**0.047**	**-0.080**	**0.017**	**-0.012**	**-0.012**	-0.002	**0.029**	**-0.775**	**0.030**	**-0.043**	-0.002	**-0.044**
	0.010	*0.005*	*0.009*	*0.005*	*0.007*	*0.005*	*0.006*	*0.004*	*0.006*	*0.005*	*0.007*	*0.006*	*0.004*	*0.005*
Milk	**0.207**	**-0.070**	**0.095**	**0.168**	**-0.707**	**-0.055**	**0.108**	**-0.067**	**-0.391**	**-0.011**	**-1.483**	**-0.172**	**0.022**	**-0.171**
	0.048	*0.020*	*0.045*	*0.027*	*0.040*	*0.020*	*0.012*	*0.019*	*0.016*	*0.005*	*0.045*	*0.012*	*0.010*	*0.011*
Eggs	**-0.125**	**-0.074**	**0.198**	**-0.071**	**0.041**	**-0.082**	**-0.165**	**-0.034**	**0.120**	**-0.044**	**-0.187**	**-0.607**	0.007	**0.159**
	0.025	*0.011*	*0.022*	*0.014*	*0.019*	*0.011*	*0.013*	*0.010*	*0.013*	*0.006*	*0.016*	*0.022*	*0.010*	*0.012*
Sugar	**-0.287**	0.016	**-0.177**	**-0.286**	**-0.115**	**0.096**	**0.054**	**0.036**	**0.188**	**-0.023**	**0.080**	-0.004	**-1.105**	**-0.197**
	0.045	*0.018*	*0.037*	*0.022*	*0.029*	*0.018*	*0.019*	*0.015*	*0.021*	*0.009*	*0.027*	*0.020*	*0.031*	*0.018*
Oil	**-0.018**	**-0.067**	**0.103**	**-0.094**	**0.078**	**0.017**	**-0.011**	**0.021**	0.003	**-0.017**	**-0.043**	**0.061**	**-0.029**	**-0.838**
	0.009	*0.004*	*0.008*	*0.005*	*0.007*	*0.004*	*0.004*	*0.003*	*0.004*	*0.002*	*0.006*	*0.005*	*0.003*	*0.007*

Note: The italicized numbers are the estimated parameter standard errors. Values in bold identify elasticity estimates that are statistically different from 0 at or below the 0.05 significance level.

Table 3.6 Hicksian Price Elasticity Estimates from the GEASI System

	Beef	Chicken	Mutton	Fish	Rice	Wheat	Pulse	Fruit	Vegetable	Onion	Milk	Eggs	Sugar	Oil
Beef	**-1.033**	**-0.064**	0.012	**0.150**	**0.261**	-0.014	**-0.049**	**0.234**	**0.345**	**0.031**	**0.202**	**-0.043**	**-0.052**	**0.021**
	0.095	*0.025*	*0.065*	*0.031*	*0.045*	*0.022*	*0.012*	*0.023*	*0.016*	*0.005*	*0.031*	*0.012*	*0.011*	*0.011*
Chicken	**-0.062**	**-0.466**	0.021	**-0.084**	**0.573**	**-0.045**	**-0.029**	**0.025**	**0.080**	-0.004	0.025	**-0.017**	**0.021**	**-0.038**
	0.024	*0.019*	*0.028*	*0.016*	*0.023*	*0.010*	*0.005*	*0.011*	*0.007*	*0.002*	*0.013*	*0.005*	*0.004*	*0.005*
Mutton	0.105	0.188	**-2.055**	**-2.729**	0.748	**1.098**	**0.514**	**-0.543**	**0.240**	**0.217**	**0.593**	**0.825**	**-0.345**	**1.144**
	0.558	*0.250*	*1.018*	*0.363*	*0.520*	*0.229*	*0.095*	*0.217*	*0.119*	*0.036*	*0.246*	*0.089*	*0.076*	*0.081*
Fish	**0.033**	**-0.019**	**-0.071**	**-0.453**	**0.217**	-0.004	**0.029**	**0.082**	**0.056**	**0.009**	**0.092**	**0.010**	0.002	**0.017**
	0.007	*0.004*	*0.010*	*0.008*	*0.010*	*0.003*	*0.001*	*0.003*	*0.002*	*0.001*	*0.004*	*0.001*	*0.001*	*0.001*
Rice	**0.028**	**0.063**	0.009	**0.104**	**-0.523**	**0.039**	**0.023**	**0.030**	**0.102**	**0.019**	**0.020**	**0.019**	**0.014**	**0.054**
	0.005	*0.003*	*0.007*	*0.005*	*0.008*	*0.002*	*0.001*	*0.002*	*0.001*	*0.000*	*0.002*	*0.001*	*0.001*	*0.001*
Wheat	-0.057	**-0.190**	**0.525**	-0.074	**1.484**	**-2.049**	0.024	**0.217**	**0.107**	-0.006	-0.077	**-0.143**	**0.111**	**0.129**
	0.089	*0.043*	*0.109*	*0.049*	*0.064*	*0.066*	*0.021*	*0.037*	*0.028*	*0.010*	*0.052*	*0.021*	*0.018*	*0.020*
Pulse	**-0.086**	**-0.052**	**0.106**	**0.229**	**0.385**	0.010	**-0.996**	**0.050**	**0.218**	0.007	**0.192**	**-0.122**	**0.040**	0.019
	0.021	*0.009*	*0.020*	*0.011*	*0.015*	*0.009*	*0.018*	*0.008*	*0.011*	*0.005*	*0.014*	*0.011*	*0.008*	*0.009*
Fruit	**0.244**	**0.027**	**-0.067**	**0.385**	**0.292**	**0.056**	**0.030**	**-1.253**	**0.150**	**0.017**	0.023	0.000	**0.026**	**0.070**
	0.024	*0.012*	*0.027*	*0.014*	*0.021*	*0.010*	*0.005*	*0.017*	*0.006*	*0.002*	*0.013*	*0.005*	*0.004*	*0.005*
Vegetable	**0.112**	**0.027**	**0.009**	**0.081**	**0.312**	**0.009**	**0.040**	**0.047**	**-0.695**	**0.022**	**-0.014**	**0.036**	**0.032**	**0.045**
	0.005	*0.002*	*0.005*	*0.003*	*0.003*	*0.002*	*0.002*	*0.002*	*0.003*	*0.001*	*0.003*	*0.002*	*0.002*	*0.002*
Onion	**0.063**	-0.009	**0.052**	**0.082**	**0.357**	-0.003	0.008	**0.032**	**0.140**	**-0.758**	**0.053**	**-0.026**	0.006	0.001
	0.010	*0.005*	*0.009*	*0.005*	*0.006*	*0.005*	*0.006*	*0.004*	*0.006*	*0.005*	*0.007*	*0.006*	*0.004*	*0.005*
Milk	**0.312**	0.040	**0.108**	**0.640**	**0.283**	-0.029	**0.168**	0.034	**-0.067**	**0.041**	**-1.415**	**-0.121**	**0.047**	**-0.039**
	0.048	*0.020*	*0.045*	*0.025*	*0.036*	*0.020*	*0.012*	*0.019*	*0.015*	*0.005*	*0.045*	*0.012*	*0.010*	*0.011*
Eggs	**-0.089**	**-0.036**	**0.202**	**0.091**	**0.379**	**-0.073**	**-0.145**	0.000	**0.231**	**-0.026**	**-0.164**	**-0.589**	0.015	**0.204**
	0.025	*0.011*	*0.022*	*0.013*	*0.018*	*0.011*	*0.013*	*0.010*	*0.013*	*0.006*	*0.016*	*0.022*	*0.010*	*0.012*
Sugar	**-0.216**	**0.090**	**-0.169**	0.037	**0.562**	**0.114**	**0.094**	**0.105**	**0.409**	0.013	**0.126**	0.030	**-1.088**	**-0.108**
	0.045	*0.018*	*0.037*	*0.022*	*0.027*	*0.018*	*0.019*	*0.015*	*0.021*	*0.009*	*0.027*	*0.020*	*0.031*	*0.018*
Oil	0.016	**-0.031**	**0.107**	**0.062**	**0.405**	**0.025**	0.008	**0.054**	**0.110**	0.001	**-0.020**	**0.078**	**-0.021**	**-0.794**
	0.009	*0.004*	*0.008*	*0.005*	*0.007*	*0.004*	*0.004*	*0.003*	*0.004*	*0.002*	*0.006*	*0.005*	*0.003*	*0.006*

Note: The italicized numbers are the estimated parameter standard errors. Values in bold identify elasticity estimates that are statistically different from 0 at or below the 0.05 significance level.

Table 3.7 Expenditure Elasticity Estimates from the GEASI System

Food Item	Estimates	Std. Error
Beef	3.697	0.075
Chicken	1.095	0.038
Mutton	0.177	1.432
Fish	0.819	0.016
Rice	0.992	0.011
Wheat	0.773	0.129
Pulse	1.031	0.024
Fruit	2.225	0.036
Vegetable	0.891	0.005
Onion	0.868	0.008
Milk	2.526	0.063
Eggs	0.863	0.029
Sugar	1.726	0.050
Oil	0.834	0.011

Note: All the estimates except mutton are statistically different from 0 at 0.01 significance level

3.6 Policy Implications of Pre-committed Demand

Bangladesh has been fighting against poverty and hunger since the independence in 1971. Despite the success of substantial poverty reduction in recent years, poverty is still one of the major hurdles in the socio-economic development of Bangladesh (BBS 2017b). According to HIES 2016, about one-fourth (24.3%) of its population lives under the poverty line. In its most recent, the 7th Five Year Plan (1916-2020), the government of Bangladesh set a target to reduce poverty and extreme poverty to 18.6% and 8.9% respectively by 2020. To achieve this objective, the government initiated different social safety net programs for providing food and employment opportunities. For example, the major food support programs in Bangladesh include vulnerable group feeding (VGF) program, food for works, vulnerable group development (VGD), Test relief (TR), community nutrition program, and Gratuitous Relief. In these food support programs, the types and amount of food commodity can be selected based on the presence and level of pre-commitment. Since the presence of pre-commitment is found on rice, pulse, vegetables and onion, these are the most important food items in the basket of Bangladeshi households. So, the government can provide those food items as a part of food support program considering the pre-commitment percentage. Based on the presence of pre-committed demand government can also ensure sufficient supply of rice, pulse, vegetables and onion since economic factors cannot influence the demand of those food items in the pre-committed portion and thus households want to consume those food items in any means. Besides, the government of Bangladesh runs open market sale program where necessary commodities are sold in cheaper price to support the lower income group. In that case, government can include rice, pulse, vegetables and onion under the program since these are more of staple food items for Bangladeshi households based on the presence of pre-committed demand.

3.7 Summary and Conclusion

The economy of Bangladesh is growing very sharply during the last three decades. The country consistently achieved over 6% growth rate in GDP, from 2010-11 to 2018-19 (BBS 2018). Industrialization, urbanization and per capita income are also mounting up due to massive economic growth. The changes in socioeconomic and demographic factors lead to change in food demand and consumption pattern in Bangladesh. For example, Mottaleb et al. (2018) found that Bangladesh, the traditional rice-consuming country is consuming less rice and more higher value products such as meat, fish and egg than before (Mottaleb et al. 2018; BBS 2017b). Furthermore, the pre-committed demand, the portion of demand that consumers are willing to consume regardless of any change in economic factors, is expected to observe in the food demand of Bangladeshi household due to have lower income and excessive dependence on some food items. Although Demand is almost perfectly inelastic over the pre-committed portion of demand, consumers response significantly to change in price once this pre-committed portion of demand is satisfied (Rowland et al. 2017). Own-price elasticities are supposed to be more elastic in the presence of pre-committed demand. Thus, estimation of consumer demand ignoring pre-commitments leads to biased estimate when pre-committed demand exists in consumer behavior.

But previous studies on consumer demand analysis in Bangladesh did not account for this important phenomenon in their demand models, which may result in biased estimates of elasticities of food commodities. Therefore, it is really important for policy makers, market participants and researchers to understand the food demand system of the consumer in Bangladesh considering the changing socioeconomic and demographic scenarios, and pre-commitments to ensure food and nutritional security, price stability, poverty alleviation and appropriate import-export policy of the country. However, despite the need of accurate demand estimation with advanced model, there is no recent demand study in Bangladesh to understand the consumer behavior subject to changing consumption pattern. Hence, the main objective of this study is to explore the recent picture of demand for major food items in Bangladesh in the presence of pre-committed demand component.

This study concentrates on the demand estimation of 14 major food items such as beef, chicken, mutton, fish, rice, wheat, pulse, fruit, vegetables, onion, milk, egg, sugar and oil that are most commonly consumed by the households of Bangladesh. The demand analysis is based on secondary data extracted from Household Income and Expenditure Survey (HIES) of the Bangladesh Bureau of Statistics (BBS) during the years 2000, 2005, 2010, and 2016.To address the pre-committed food demand in Bangladesh, we follow the methodology of Hovannisyan and Shanoyan (2018) which employed the generalized EASI (GEASI) demand model. Importantly, this is the first application of this model to estimate food demand structure in Bangladesh.

The evidence of pre-committed demand is found in case of rice, pulse, vegetables and onion since the pre-committed demand coefficients for these food items are positive and statistically significant. Pre-committed demand accounts for 16.20%, 32.04%, 9.73% and 21.82% of total rice, pulse, vegetables and onion demand, respectively. All the Marshallian and the Hicksian own-price elasticity estimates are negative and statistically significant and therefore, consistent with the theory of demand. The Marshallian own-price elasticities of chicken (-0.51), fish (-0.61), rice (-0.91), vegetables (-0.81), onion (-0.78), egg (-0.61) and oil (-0.82) appear to be inelastic while the elasticities of beef (-1.19), mutton (-2.06), wheat (-2.06), fruit (-1.34), milk (-1.48) and sugar (-1.11) are found to be elastic. The Hicksian own-price elasticities estimated to be more inelastic than that of the Marshallian elasticities, as for example, the Marshallian own-price elasticity of rice is -0.91 whereas it is -0.52 in case of the Hicksian estimate. Similarly, the Hicksian own-price elasticity for fish (-0.07), vegetables (-0.70), onion (-0.76), egg (-0.59) and oil (-0.79) are more inelastic compare to the Marshallian elasticities. Likewise, the Hicksian own-price elasticities for beef (-1.03), mutton (-2.06), wheat (-2.05), fruit (-1.25), milk (-1.42) and sugar (-1.09) are also own-price elastic but slightly lower in magnitude. Overall, the magnitude of the Hicksian own-price elasticity estimates are less than that of the Marshallian elasticity.

Most of the cross-price elasticity estimates of both the Marshallian and the Hicksian are statistically significant and consistent with expectations. Out of total 182 cross-price elasticity estimates, 150 Marshallian and 145 Hicksian estimates are found to be significant. In case of the Marshallian, substitution relationship is found between rice and wheat (0.029), milk and beef (0.21), milk and mutton (0.10), and milk and fish (0.17). On the other hand, complementary relationship is found between different meat items, rice and fish (-0.08), milk and chicken (-0.07), and milk and egg (-0.17), fruit and vegetable (-0.14). In case of Hicksian elasticities, rice is found to be substitute to all food items. Similarly, vegetable is substitute to all food items except milk. Beef and fish are estimated to be substitute to each other while different meat categories are mostly complementary to each other.

All the expenditure elasticities are found to be positive and statistically significant. The expenditure elasticities of beef (3.70), fruit (2.23), milk (2.53) and sugar (1.73) are elastic but elasticities of mutton (0.18), fish (0.82), wheat (0.77), vegetable (0.89), onion (0.87), eggs (0.86), and oil (0.83) are inelastic. On the other hand, the expenditure elasticities of chicken (1.10), rice (0.99), and pulse (1.03) are approximately unitary elastic.

The findings of this study have a potential to expand the literature on food demand in Bangladesh as well as in developing countries and also would be helpful to the researchers in the field of social sciences to find out important information and research questions for future researches. Based on pre-committed demand, policy makers can formulate effective policies on food and nutritional security as well as agricultural and trade policies to ensure sustainable economic growth and poverty alleviation of the country. Furthermore, the results of this study would be helpful to food industry participants to maximize their profit by a clear understanding of pre-commitment level and the distribution of price and expenditure elasticity estimates. Future research can concentrate on identifying the factors influencing pre-committed demand and also the policy implication of pre-committed demand in case of food, agricultural and trade policies.

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Chapter 4 - Deficit or Surplus Rice Production in Bangladesh: Evidence from Rice Production and Consumption Forecast

4.1 Introduction

Bangladesh is the highest per capita rice consuming and the fourth largest rice producing country in the world (World Rice Production 2017). The cereal plays a vital role to the national economy of Bangladesh by contributing to GDP, creating employment and attaining food security of the country. The contribution of crops sub-sector in GDP in 2015-16 is 8.15% among which the major contribution comes from rice production (BBS 2017a). Rice is the major crop in Bangladesh which provides 91% of total food grain production and covers 80% of total cropped area (Rahman et al. 2016). Rice is grown in three different seasons in Bangladesh: Boro (Winter crop, Nov-Dec to Mar-Apr), Aus (Summer crop, mid Mar-Apr to mid Jun-Jul) and Aman (Monsoon crop, mid Jul to mid Nov-Dec). Rice is also a staple food in Bangladesh where per capita consumption is 367.19 gm per day which is very high compare to wheat consumption as 19.83 gm per day (BBS 2017b).

Rice production in Bangladesh has more than tripled since the independence of the country, estimated as 10090 thousand metric tons in 1972 to 34578 thousand metric tons in 2016 (USDA 2018). The green revolution in rice production was possible due to introduction of high yielding varieties, use of improved technology and government support to rice farmers. However, the growth in rice production was counterbalanced by the growth in rice consumption since the consumption has also increased more than threefold from the liberation, calculated as 10418 thousand metric tons in 1972 to 35000 thousand metric tons in 2016, because of growth in population of the country. Thus, the trend in rice consumption closely follows the trend in rice production, increasing gradually over the last four decades.

The study of rice production and consumption trends in Bangladesh has important implications for poverty, food security, price stabilization and economic development. Since rice is a staple food item in Bangladesh and demand of rice is also inelastic (Huq and Arshad 2010), the deficit production or any significant reduction in aggregate supply of rice causes a significant increase in price of rice and welfare losses of consumers. Bangladesh experienced a rapid price hike in rice in 1998, 2007 and 2017 due to reduction in aggregate rice production caused by massive flood throughout country. Moreover, price increase in staple food item like rice may have a large income effect through reducing income for other needs (Wood et al. 2012). On the other hand, the surplus production tends to result in lower price which has a significant negative impact on farm profitability and household wellbeing in rural areas where the rice farming is the main source of income. Therefore, government and policy makers always attempt to make a balance between demand and supply of necessary food items to insure food security and price stabilization in a developing country, Bangladesh.

Forecasting, an activity to calculate or predict some future event or condition, is an important tool for policy makers to make a balance between demand and supply of food items. Forecasting results are useful to understand the future demand and supply situation of a commodity whether the supply would be sufficient or not to meet up the demand of the population. Forecasting particular on rice production and consumption is important to formulate policies on rice production, distribution and import-export decisions. For example, if forecasting results indicates a significant amount of deficit rice production in current year, the government can balance the deficit amount by importing sufficient amount of rice to prevent any food crisis in the country. Additionally, forecasting can give an idea to policy makers whether the government needs to encourage domestic production and/or needs to import rice in future to ensure food security as well as price stabilization. If deficit is too large, the government can consider encouraging farmers to increase domestic production instead of importing to save valuable foreign currency. On other hand, forecasting evidence can also assist the government to make decision about utilizing surplus production of rice to support the farming community. Forecasting is also useful for entrepreneurs and farmers to make their business and production plan. Thus, considering the importance of forecasting, this study attempts to forecast rice production and consumption to figure out the deficit or surplus production in Bangladesh in future.

Forecasting literature includes numerous forecasting techniques based on properties of time series data. Moving average, weighted moving average, double moving average, linear trend model, quadratic trend model, exponential smoothing, ARIMA (Autoregressive Integrated Moving Average), VAR (Vector Autoregressive) model etc. are some example of forecasting model. ARIMA and exponential smoothing models are extensively used forecasting models. Several attempts have been made to forecast rice area and production in Bangladesh using Autoregressive Integrated Moving Average (ARIMA) model. Rahman et al. (2016) forecasted Aus rice area and production in Bangladesh from 2015 to 2024 using ARIMA (1,1,5) and ARIMA (1,1,4) models respectively. The Aus rice production were forecasted 1966.94 thousand M. tons and 1781.55 thousand M. tons in 2018 and 2024 respectively. The forecasted Aus area and production showed a decreasing trend. Hamjah (2014) used ARIMA model for forecasting Aus, Aman and Boro rice production using rice production data starting 1972 through 2006. The findings showed an increasing trend both from Boro and Aman rice production forecast but a decreasing trend from Aus production in Bangladesh. Awal and Siddique (2011) studied Aus, Aman and Boro rice production forecast from 2008-09 to 2012-13 in Bangladesh employing ARIMA model. The study found that ARIMA models were more efficient compared to deterministic models for short-term forecasting. ARIMA (4,1,4), ARIMA (2,1,1) and ARIMA (2,2,3) models were the best fitted model for short run forecasting of Aus, Aman, and Boro rice respectively. Rahman (2010) conducted Boro rice production forecasting from 2008-09 through 2012-13 in Bangladesh using ARIMA model and found an increasing trend of Boro rice production.

The forecasting of previous studies in Bangladesh was mostly based on a specific crop season like Boro or Aus or Aman rice crop and moreover the forecasting periods of those studies has become past except Rahman et al. (2016). Although few studies projected Aus, Aman, and Boro crops production together but those studies did not consider the gap between total rice production and consumption to understand future deficit or surplus which becomes extremely important due to recent price hike in rice. Furthermore, previous studies were based on ARIMA model only and did not use any test to evaluate out-of-sample accuracy of the forecasting models. To bridge these gaps, this study will focus on both forecasting of total rice production and consumption by employing different techniques of forecasting with accuracy test. Specifically, the present study will empirically contribute to forecasting literature in Bangladesh by using exponential smoothing models of double exponential and Holt-Winter and approaching model accuracy measures such as mean square error (MSE), mean absolute percentage error (MAPE), and mean absolute error

(MAE). The findings of the study can be helpful for policy makers to formulate effective policies regarding rice production and distribution to improve the socio-economic welfare of the country.

4.2 Objectives of the Study

The general objective of the study is to figure out the amount of deficit or surplus production in Bangladesh for both short-run (5 years) and long-run (35 years). However, the specific objectives are:

i) to forecast total rice production in short-run and long-run;

ii) to forecast total rice consumption in short-run and long-run and

iii) to quantify the amount of total surplus or total deficit production both in short-run and long-run.

4.3 Literature Review

Forecasting literature includes numerous forecasting techniques based on properties of time series data. Moving average, weighted moving average, double moving average, linear trend model, quadratic trend model, exponential smoothing, ARIMA (Autoregressive Integrated Moving Average), VAR (Vector Autoregressive) model etc. are some example of forecasting model. ARIMA and exponential smoothing models are extensively used forecasting models. Several attempts have been made to forecast rice area and production in Bangladesh using Autoregressive Integrated Moving Average (ARIMA) model. Rahman et al. (2016) forecasted Aus rice area and production in Bangladesh from 2015 to 2024 using ARIMA (1,1,5) and ARIMA (1,1,4) models respectively. The Aus rice production were forecasted 1966.94 thousand M. tons and 1781.55 thousand M. tons in 2018 and 2024 respectively. The forecasted Aus area and production showed a decreasing trend. Hamjah (2014) used ARIMA model for forecasting Aus, Aman and Boro rice production using rice production data starting 1972 through 2006. The findings showed an increasing trend both from Boro and Aman rice production forecast but a decreasing trend from Aus production in Bangladesh. Awal and Siddique (2011) studied Aus, Aman and Boro rice production forecast from 2008-09 to 2012-13 in Bangladesh employing ARIMA model. The study found that ARIMA models were more efficient compared to deterministic models for short-term forecasting. ARIMA (4,1,4), ARIMA (2,1,1) and ARIMA (2,2,3) models were the best fitted model for short run forecasting of Aus, Aman, and Boro rice respectively. Rahman (2010) conducted Boro rice production forecasting from 2008-09 through 2012-13 in Bangladesh using ARIMA model and found an increasing trend of Boro rice production.

A considerable body of research has forecasted production and consumption of different agricultural commodities worldwide. Most of the studies used univariate ARIMA approach to forecast these commodities. Rejesus et al. (2012) forecasted global rice consumption using three univariate forecasting techniques: double exponential smoothing, Holt-Winters smoothing, and ARIMA models. Among these models, double exponential smoothing generated better out-of-sample forecast for long-term forecasting whereas ARIMA model was superior for short-term forecasting. Global rice consumption was forecasted to increase around 490 million tons in 2020 and to about 650 million tons in 2050. Badmus and Ariyo (2011) forecasted maize area and production in Nigeria using ARIMA model for long-term forecasting from 2006-07 to 2019-2020. Iqbal et al. (2005) projected wheat area and production in Pakistan. The study used ARIMA model for long-term projection of total 20 years starting from 2000-01 through 2021-22.

4.4 Methods

4.4.1 Preliminary test of time series properties: stationarity test

The first step in regression analysis of time series data is to test the stationarity of each series. A time series is (weakly) stationary if its mean and variance are constant over time and the covariance between the two time periods depends only on the distance between the two time periods (Gujarati 2003). On the other hand, a nonstationary time series has a time-varying mean or a time-varying variance or both. Nonstationary time series is not appropriate for the purpose of forecasting rather we can use it to study only for the time period under consideration. So, we have to make the time series data stationary for forecasting purpose if it appears to be non-stationary in test results. Time series literature includes unit root test as a formal test to examine the stationarity of a series. However, we can also get a preliminary idea about the nature of a time series by plotting the data or graphical analysis. In that case, time series graph having any types of trend suggests non-stationarity of the data while having no trend implies stationarity property of the series.

4.4.2 Graphical analysis

The line plot of time series data gives an initial idea about the nature of the series. For instance, both line plot of annual rice production and consumption (Figure 1) show an upward trend, perhaps suggesting that the mean value are changing and thus the time series are not stationary.

4.4.3 The unit root test

Unit root test is widely used and formal test of stationarity in time series analysis. In this study, we used Dickey-Fuller test (Dickey and Fuller 1979), Augmented Dickey-Fuller (DF) test (Dickey and Fuller 1981), Augmented Dickey-Fuller Generalized Least Squares (ADF-GLS) test

(Elliot et al. 1996) and Philips-Perron test (Phillips and Perron 1988) to test the unit root or the presence of non-stationarity in the time series. The null hypothesis in the above-mentioned test is that the time series is not stationary i.e. there is a unit root in the time series variable. The series is stationary if we can reject the null hypothesis.

4.5 Empirical Methods

To forecast rice production and consumption, we considered univariate autoregressive model such as ARIMA and exponential smoothing model such as double exponential and Holt-Winters approaches.

4.5.1 Forecasting models

4.5.1.1 Univariate autoregressive models: ARIMA approach

The ARIMA model which is a combination of AR and MA models, used to forecast rice production and consumption in this study. An autoregressive model (AR) model is a univariate time series model that uses p lagged values to explain current values whereas a moving average (MA) model uses q lagged values of error terms to explain current values. The ARIMA (*p,d,q*) represents an autoregressive integrated moving average time series where *p* denotes the number of autoregressive terms, *d* the number of time the series has to be differenced before it becomes stationary and *q* the number of moving average terms. The general form of the ARIMA (*p,q,d*) can be written as:

$$Y_t = \beta_1 Y_{t-1} + \ \dots\dots\dots + \beta_p Y_{t-p} + \theta_1 \varepsilon_{t-1} + \ \dots\dots\dots + \theta_q \varepsilon_{t-q} + \varepsilon_t \qquad (1)$$

Thus an ARIMA (1,1,1) model implies that underlying time series has to be differenced once before it becomes stationary and it has one AR and one MA terms. Forecasting using an

ARIMA model consists of three parts: identification, estimation of parameters, and diagnostic checking. The identification step involves determining the appropriate value of p, d and q by using various techniques. We used information criteria like AIC (Akaike Information Criteria) and SIC (Schwartz Information Criteria) in this study to identify the appropriate number of p and q. Generally, the model providing the lowest AIC and/or SIC is considered the best model. In this study, we used graphical analysis, the correlogram test and unit root test to determine d. The estimation of parameters of the model can be done by maximum likelihood (MLE) method if there is any MA term, otherwise the model can be estimated by OLS method. The diagnostic checking of the model is performed by using correlogram of the residuals and SK (skewness-kurtosis) test of normality.

In the empirical research, many advantages of the ARIMA model are found and support the ARIMA as a proper way in especially short-term time series forecasting (Box and Jenkins 1970). Taking advantage of its strictly statistical approach, the ARIMA method only requires the prior data of a time series to generalize the forecast. Hence, the ARIMA method can increase the forecast accuracy while keeping the number of parameters to a minimum. Some major disadvantages of ARIMA forecasting are: first, some of the traditional model identification techniques for identifying the correct model from the class of possible models are difficult to understand and usually computationally expensive. This process is also subjective and the reliability of the chosen model can depend on the skill and experience of the forecaster. Second, the underlying theoretical model and structural relationships are not distinct as some simple forecast models such as simple exponential smoothing and Holt-Winters (O'Donovan 1983).

4.5.1.2 Exponential smoothing approach

Exponential smoothing is a univariate forecasting approach that assigns larger weight to more recent observations and exponentially decreasing weights to past observations. Single exponential, double exponential, and the Holt-Winters are three different exponential smoothing methods used for forecasting. Single exponential smoothing approach appropriate only for time-series data that exhibit no linear or higher-order trends. The smoothed or forecasted value S_t for any period *t* is estimated inn the single exponential method using the following equation:

$S_t = \propto Y_t + (1 - \propto) S_{t-1}$ (2) for $t = 1,2, \ldots.., T$

Where Y_t is the current observation and $\propto$ is a smoothing parameter which can be any value between 0 and 1 ($0 \leq \propto \leq 1$). The value of $\propto$ is estimated by minimizing the in-sample mean squared forecast error. The above equation can be written as a weighted moving-average with continuous substitution of S_{t-1}:

$$S_t = \propto \sum_{i=0}^{T-1} (1 - \propto)^i \, Y_{t-i} + (1 - \propto)^T S_0 \qquad (3)$$

Where, S_0 is the initial value. The equation shows that the smoothed or forecasted value S_t is a weighted combination of all previous values in the time series where the most recent observation receives the highest weight and then geometrically decreasing weights to observations further in the past. The shortcoming of the single exponential method is that it only provides a single value for the entire forecast horizon. That means, the forecast for all future time periods equal the same value. This is consistent with the underlying idea of a stationary time series that has no trend.

Hence single exponential method is not appropriate for this study since both rice production and consumption has an upward trend over time.

The double exponential or the Holt-Winters smoothing method may be more appropriate if the time-series variable of interest has a trend. The single smoothed series in equation is again smoothed in double exponential soothing as follows:

$$S_t^{[2]} = \propto Y_t + (1-\propto) S_{t-1}^{[2]} \qquad (4)$$

The initial values S_0 and $S_0^{[2]}$ are obtained using the following equations:

$$S_0 = \widehat{\beta_0} - \left[\frac{1-\propto}{\propto}\right]\widehat{\beta_1} \qquad (5)$$

$$S_0^{[2]} = \widehat{\beta_0} - 2\left[\frac{1-\propto}{\propto}\right]\widehat{\beta_1} \qquad (6)$$

The smoothing parameter $\propto$ is obtained by minimizing the in-sample mean squared forecast error, same as single exponential method. The coefficients $\widehat{\beta_0}$ and $\widehat{\beta_1}$ are calculated by following regression model using OLS:

$$Y_t = \widehat{\beta_0} + \widehat{\beta_1} t \qquad (7)$$

In double exponential method, the *n*th-step ahead forecast is found by using:

$$\hat{Y}_{t+n} = E_t + nT_t \qquad (8)$$

Where

$$E_t = 2S_t - S_t^{[2]} \qquad (9)$$

$$T_t = \left[\frac{1-\propto}{\propto}\right]\left(S_t - S_t^{[2]}\right) \quad (10)$$

The Holt-Winters smoothing approach is the most general among the three smoothing methods because it can accommodate both trends and seasonality in the time-series (Holt 2004). The Holt-Winters method based on a base level and a trend estimates too represented by:

$$\hat{Y}_{t+n} = E_t + nT_t \quad (11)$$

Where

$$E_t = \propto Y_t + (1-\propto)(E_{t-1} + T_{t-1}) \quad (12)$$

$$T_t = \beta(E_t - E_{t-1}) + (1-\beta)T_{t-1} \quad (13)$$

We can use equation (11) to forecast *n* time periods in the future where *n* = 1,2,3, and so on. The forecast for time period $t+n$ ($\hat{Y}_{t+n}$) is summation of the base level at time period t (E_t) and the expected influence of the trend during the next n time periods (nT_t). $\propto$ and β are two smoothing parameters which can be any value between 0 and 1 ($0 \leq \propto \leq 1$, $0 \leq \beta \leq 1$). The value of the smoothing parameters is chosen by minimizing the in-sample penalized sum-of-squared errors. If there is an upward trend in the data, E_t tends to be larger than E_{t-1}, making the quantity $(E_t - E_{t-1})$ in equation positive. This tend to increase the value of the trend adjustment factor T_t. Alternatively, if there is a downward trend in the data, E_t tends to be smaller than E_{t-1}, making the quantity $(E_t - E_{t-1})$ in equation negative. This tend to decrease the value of the trend adjustment factor T_t. Initial values E_0 and T_0 are obtained by estimating the following regression model using OLS:

$$Y_t = E_0 + T_0 t \quad (14)$$

4.5.2 Out-of-sample forecast evaluation: MSE, MAPE and MAE

The mean square error (*MSE*) criterion, the mean absolute percentage error *(MAPE)*, and the mean absolute error (*MAE*) criterion are used to evaluate the out-of-sample forecasting accuracy of the above-mentioned forecasting models. These tests identify the best approach to forecast rice production and consumption at different forecast horizons. Out-of-sample forecast evaluation is conducted by splitting the time-series data such that the last 5-years (*T* - 5), the last 10-years (*T* - 10), and the last 20-years (*T* - 20), respectively, are left out of the estimating sample and then, to assess forecast accuracy, forecasted values of the left out periods are compared to the actual observed values by calculating differences between forecasted and actual values (Rejesus et al. 2012). For example, if time-series data comprise from 1971-2017, then in case of out-of-sample evaluation for a 5-year forecast horizon, the time series will be split such that the data from 1971-2012 will be used to estimate the parameters, and the remaining actual data (2013-2017) will be used to estimate the error between actual and forecasted values through MSE, MAPE and MAE. The same splitting procedure is used for the 10-year and 20-year forecast horizons. The MSE, MAPE and MAE can be calculated as follows:

$$\text{MSE}=\frac{1}{n}\sum_{i=1}^{n}\hat{e}_i{}^2$$

$$\text{MAPE}=\frac{100}{n}\sum_{i=1}^{n}\left|\frac{\hat{e}_i}{y_i}\right|$$

$$\text{MAE}=\frac{1}{n}\sum_{i=1}^{n}|\hat{e}_i|$$

$$\hat{e}_i = y_i - \hat{f}_i$$

Where, y_i is the actual value for ith observation in the time series and $\hat{f}_i$ is out-of-sample forecast for this observation and thus $\hat{e}_i$ is the forecasting error i.e. the difference between actual and forecasted time series observations. A forecast model with lower MSE, MAPE and MAE is preferred.

4.6 Data

We collect the time series data on rice production and consumption in Bangladesh from USDA's (United States Department of Agriculture) foreign agricultural service online database (USDA 2018). The forecasting analyses are performed considering total 57-year data of annual rice production and rice consumption from 1960-61 through 1916-17. Annual rice production is the sum of all three seasonal rice crops i.e. Boro, Aus and Aman whereas annual rice consumption was calculated from the following identity: Beginning stock + Production + Imports = Ending Stock + Consumption + Exports. The rice production data from Bangladesh government is also available in different publications by BBS (Bangladesh Bureau of Statistics) from 1970-71 to 20167-17. We preferred USDA data over BBS data because of covering longer period which is better for forecasting analysis. Moreover, BBS has only annual rice production data but no annual rice consumption data.

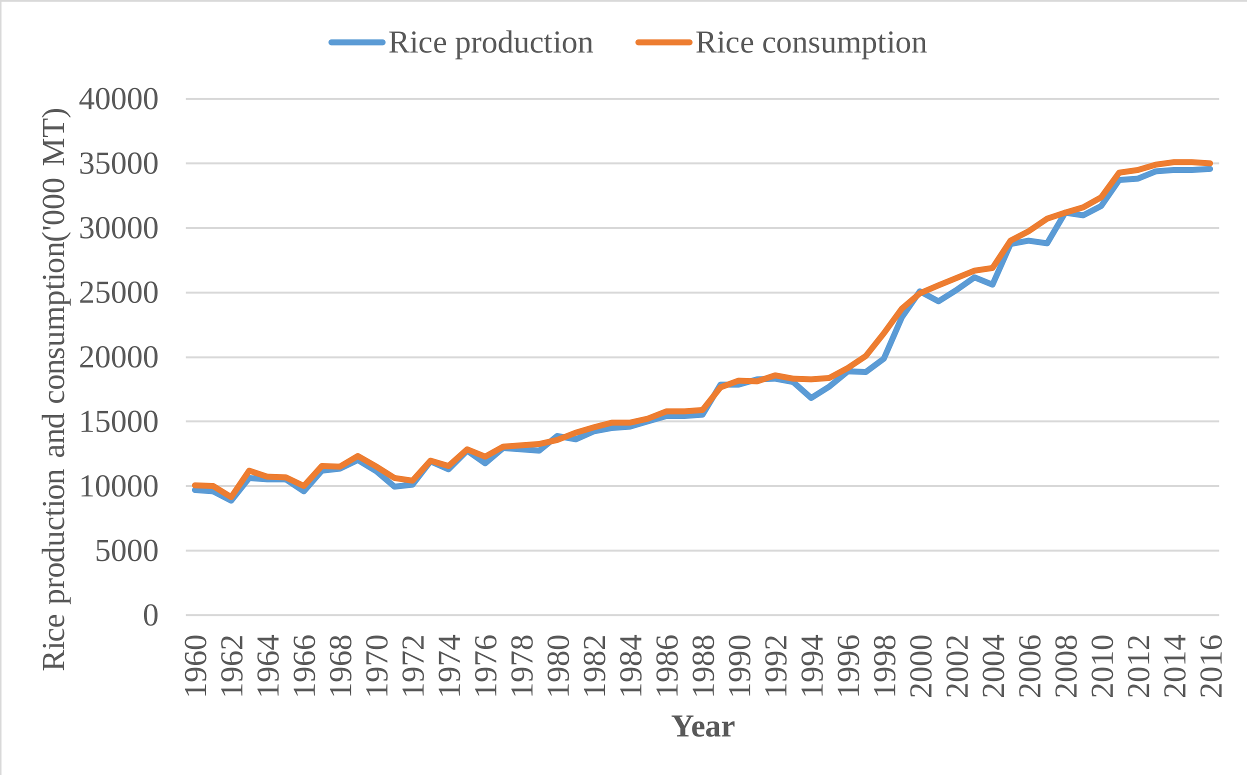

Figure 4.1 Annual rice production and consumption in Bangladesh from 1960-61 to 2016-17

Figure 4.1 shows that both annual rice production and consumption have an increasing trend with similar pattern. The production increases more than three-fold in 2016-17 compare to 1960-61. Bangladesh produced the highest amount of rice in her history in 1916-17 estimated as 34578 thousand metric tons while it was only 9672 thousand metric tons in 1960-61. Likewise, consumption has more than tripled too from 10080 thousand MT in 1960-61 to 35000 thousand MT in 2016-17.

4.7 Results and Discussion

4.7.1 Test of stationarity

Graphical analysis shows that perhaps both annual rice production and consumption are nonstationary in level for having an upward trend but stationary in first difference for having no trend. Figure 4.2 suggests that time series are stationary after taking first difference between two successive observations of the original series.

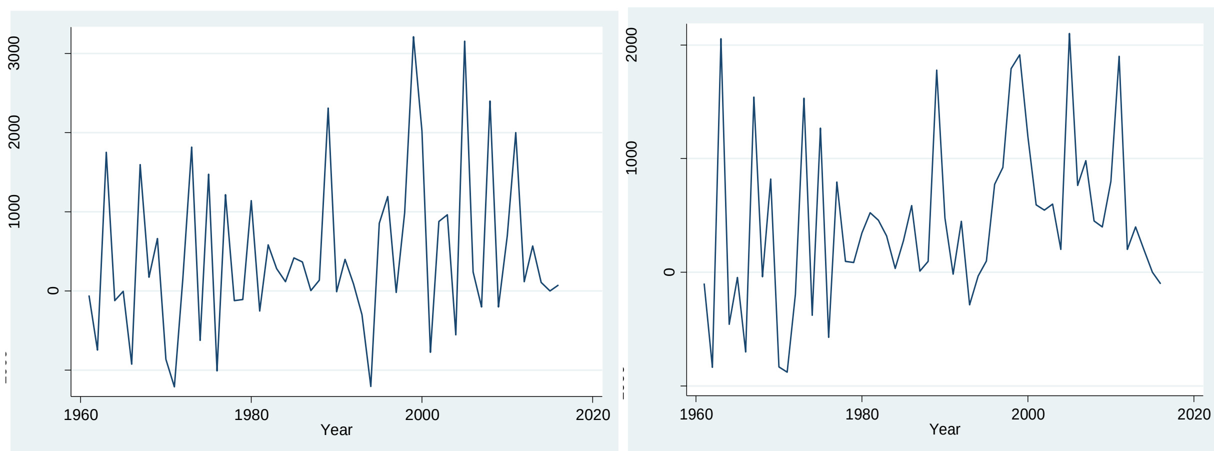

Figure 4.2 Annual rice production (left) and consumption (right) in first difference in Bangladesh from 1960-61 to 2016-17

Unit root test results further confirm the non-stationarity of both series in level and the stationarity of those two series in first difference. Based on DF, ADF, ADF-GLS and PP test, Table 4.1 indicates both production and consumption time series are not stationary in levels. The series become stationary after first differencing that means the series are integrated of order one.

Table 4.1 Unit Root Result for Rice Production and Consumption Series

Unit Root Test	Time Series	Test statistics	1% critical value	5% critical value	Decision
Dickey Fuller	Rice Production in level	-1.821	-4.137	-3.494	Nonstationary
	Rice Consumption in level	-1.670	-4.137	-3.494	Nonstationary
	Rice Production in first difference	-9.139	-4.139	-3.495	Stationary
	Rice Consumption in first difference	-7.846	-4.139	-3.495	Stationary
Augmented Dickey Fuller	Rice Production in level	-1.204	-4.141	-3.496	Nonstationary
	Rice Consumption in level	-1.359	-4.141	-3.496	Nonstationary
	Rice Production in first difference	-4.319	-4.143	-3.497	Stationary
	Rice Consumption in first difference	-4.773	-4.143	-3.497	Stationary
ADF-GLS	Rice Production in level	-1.042	-3.743	-3.140	Nonstationary
	Rice Consumption in level	-0.906	-3.743	-3.140	Nonstationary
	Rice Production in first difference	-6.572	-3.747	-3.145	Stationary
	Rice Consumption in first difference	-4.566	-3.747	-3.145	Stationary
Phillips-Peron	Rice Production in level	-1.680	-4.137	-3.494	Nonstationary
	Rice Consumption in level	-1.652	-4.137	-3.494	Nonstationary
	Rice Production in first difference	-9.351	-4.139	-3.495	Stationary
	Rice Consumption in first difference	-7.849	-4.139	-3.495	Stationary

4.7.2 Evaluation of forecasting models

First, we estimated AIC and SIC values for total 49 ARIMA models including all combinations of AR and MR terms from o to 6 lags. We identified ARIMA (0,1,1) and ARIMA (1,1,2) models as the best model to forecast rice production and consumption respectively based on information criteria. Among all combinations, the lowest value of both AIC (937.70) and SIC (943.78) were observed in ARIMA (0,1,1) model in case of rice production series. We found different model in case of rice consumption series, where the lowest values of both AIC (900.83) and SIC (910.96) were in ARIMA (1,1,2) model. ARIMA (0,1,1) and ARIMA (1,1,2) models were also fitted on diagnostics test based on autocorrelation and normality test. To estimate the parameters of the double exponential and the Holt-Winter model, we applied optimization technique described in methodology section.

We evaluated out-of-sample forecasting performance of the ARIMA model, the double exponential and the Holt-Winter model for both production and consumption series based on MSE, MAPE and MAE criteria. Table 4.2 indicates that ARIMA model has the lowest MSE, MAPE and MAE for 5-year forecast horizon (i.e. estimated the models excluding last 5-year observations and then forecasted for the excluded 5-year period to evaluate the difference or error between forecasted result and actual observation). This 5-year forecast horizon result perhaps suggests that the ARIMA model is preferred over the double exponential and the Holt-Winter model for short term forecasting of 5-year period. On the other hand, the Holt-Winter and the double exponential models have the lowest MSE, MAPE and MAE for 10-year forecast horizon and 20-year forecast horizon respectively for both series.

Table 4.2 Out-of-Sample Forecast Evaluation among Different Forecasting Models by MSE, MAPE and MAE Criteria

Forecast Horizon and Evaluation Criteria	Rice Production			Rice Consumption		
	ARIMA (0,1,1)	Double Exponential	Holt-Winter	ARIMA (1,1,2)	Double Exponential	Holt-Winter
A. 5-year forecast horizon (2012-13 to 2016-17)						
MSE	402572	3852112	3023273	1208780	4535494	4257141
MAPE	0.01343	0.04756	0.04211	0.02779	0.05115	0.05085
MAE	463.8	1640	1452	972.4	1791	1780
B. 10-year forecast horizon (2007-08 to 2016-17)						
MSE	3222460	3242940	665443	2134839	3866309	1223200
MAPE	0.04963	0.04208	0.02058	0.03728	0.04314	0.02258
MAE	1657	1407	677.8	1275	1484	775.5
C. 20-year forecast horizon (1997-98 to 2016-17)						
MSE	6.94e+07	6.05e+07	7.46e+07	7.03e+07	5.93e+07	6.69e+07
MAPE	0.2492	0.2319	0.2582	0.2512	0.2309	0.2454
MAE	7580	7062	7855	7754	7125	7571

4.7.3 Rice production and consumption forecast in the short-run

Table 4.3 represents the short-run forecast results for rice production and consumption starting from 2018-19 through 2022-23 by ARIMA model. The forecasting results show that both rice production and rice consumption is increasing in short-run. However, the country might experience small deficit in rice production in coming 5 years based on ARIMA forecasting. The largest deficit might be in the year 2019-20, estimated as 391thousand metric tons whereas the lowest deficit might be in 2022-23, calculated as 208 thousand metric tons.

Table 4.3 Forecast of Rice Production and Consumption in Bangladesh by ARIMA Model from 2018-19 to 2022-23

Year	ARIMA (0,1,1) Rice production (‘000 MT)	ARIMA (1,1,2) Rice consumption (‘000 MT)	Surplus (‘000 MT)
2018-19	35565	35818	-253
2019-20	36014	36405	-391
2020-21	36463	36693	-230
2021-22	36912	37273	-361
2022-23	37361	37569	-208

We also presented the short-run forecasting results of rice production and consumption based on Holt-Winter and double exponential models in Table 4.4. Holt-Winter model shows the similar result which was observed by ARIMA model, a small deficit in rice production ranging from 128 thousand metric tons to 229 thousand metric tons in a short-run period of 5 years. Interestingly, Double exponential model reveals different results from other two models in short-run. The forecasting results from double exponential model illustrate that both rice production and consumption is gradually increasing but increase rate in production is more than the increase rate in consumption, resulting surplus production ranging from 228 thousand metric tons in 2018-19 to 1100 thousand metric tons in 2022-23.

Table 4.4 Forecast of Rice Production and Consumption in Bangladesh by Holt-Winter and Double Exponential Models from 2018-19 to 2022-23

Year	Holt-Winter			Double Exponential		
	Rice production ('000 MT)	Rice consumption ('000 MT)	Surplus ('000 MT)	Rice production ('000 MT)	Rice consumption ('000 MT)	Surplus ('000 MT)
2018-19	35969	36198	-229	35923	35695	228
2019-20	36563	36767	-204	36388	35942	446
2020-21	37158	37336	-179	36852	36188	664
2021-22	37752	37905	-153	37317	36435	882
2022-23	38347	38474	-128	37781	36681	1100

4.7.4 Rice production and consumption forecast in the long-run

We forecasted rice production and consumption in the long-run up to the year 2049-50 using all three models. Table 4.5 presents the long-run forecasting results of rice production and consumption from 2024-25 to 2049-50. The results indicate that perhaps, the country is going to achieve self-sufficiency in rice production in the year 2029-30 and later on by producing more than the requirement. The surplus in rice production might be the lowest in 2024-25, estimated as 50 thousand metric tons and the highest in 2049-50, measured as 559 thousand metric tons.

Table 4.5 Forecast of Rice Production and Consumption in Bangladesh by Holt-Winter Model from 2024-25 to 2049-50

Year	Holt-Winter		Surplus ('000 MT)
	Rice production ('000 MT)	Rice consumption ('000 MT)	
2024-25	39536	39612	-77
2029-30	42508	42458	50
2034-35	45480	45303	177
2039-40	48453	48148	304
2044-45	51425	50993	432
2049-50	54397	53839	559

Table 4.6 represents the long-run forecasting results by the double exponential and the ARIMA model. Double exponential model is preferred than Holt-Winter model for 20-year forecast horizon, but both are equally preferred in 10-year forecast horizon. Double exponential

model demonstrates that rice production is going to increase at a larger rate than rice consumption, resulting rice surplus in the long-run. The surplus is increasing year by year, the lowest figure is 1537 thousand metric tons in 2024-25 and the highest figure is 6987 thousand metric tons in 2049-50. The ARIMA model, however, shows different results than Holt-Winter and double exponential models. Bangladesh may experience a small amount of rice deficit in the long-run till the year 2039-40 but the country may have rice surplus in 2044-45 and later on. The largest amount of deficit might be 302 thousand metric tons in 2025-26 whereas the largest amount of surplus might be 99 thousand metric tons in 2048-49 based on ARIMA findings.

Table 4.6 Forecast of Rice Production and Consumption in Bangladesh by Double Exponential and ARIMA Models from 2024-25 to 2049-50

Year	Double Exponential			ARIMA		
	Rice production (‘000 MT)	Rice consumption (‘000 MT)	Surplus (‘000 MT)	Rice production (‘000 MT)	Rice consumption (‘000 MT)	Surplus (‘000 MT)
2024-25	38711	37174	1537	38259	38444	-185
2029-30	41031	38407	2624	40504	40747	-243
2034-35	43356	39639	3717	42749	42818	-69
2039-40	45678	40872	4806	44994	45092	-98
2044-45	48001	42105	5896	47239	47188	51
2049-50	50324	43337	6987	49484	49442	42

To sum up, ARIMA model indicates rice deficit in the short-run as well as most of the years in the long-run. However, double exponential model illustrates rice surplus both in the short-run and the long-run as well. Furthermore, Holt-Winter approach demonstrates rice deficit from 2018-19 till 2027-28 and rice surplus from 2028-29 and onwards. Generally, ARIMA model is more appropriate in the short-run forecast whereas double exponential and Holt-Winter models are more appropriate in the long-run forecast (Rejesus *at el.*, 2012). The goal of any forecasting approach is to develop a model which represents the past behavior of a time series as much as possible. In practice, there are variety of forecasting techniques with different calculation procedure that produce different forecasting results. Hence, it is always challenging to settle on a single method to predict future values of a time series variable.

We can consider the result of all three models instead of settle on one model. The forecasting results considering all approaches indicate that Bangladesh might experience deficit in rice production in a range between the highest 391 thousand metric tons in 2019-20 and the lowest 1 thousand metric ton in 2027-28 based on ARIMA and Holt-Winter model respectively. Moreover, the deficit is gradually decreasing from the short-run to the long-run. On the other hand, the country might experience surplus in rice production, the highest 6987 thousand metric tons in 2049-50 and the lowest 3 thousand metric tons in 2040-41 based on double exponential and ARIMA model respectively. The surplus is gradually increasing form the short-run to the long-run considering all models.

The question arises at that point regarding the impact of deficit and surplus production on rice price in Bangladesh. Analyzing the historical data of rice production and rice consumption in Bangladesh from 1960-61 to 2016-17, we found that the country experienced rice deficit in most of the years; the highest was 2000 thousand metric tons in 1998-99, the second highest was 1947 thousand metric tons in 2007-08, the third highest was 1434 thousand metric tons in 1994-95 and the lowest was 41 thousand metric tons in 1973-74 (USDA, 2018). The price of rice boosted up in an unusual rate in those years and also in 2017-18 ranging from 20% to 60% depending on rice varieties. The deficit in rice production in 1998-99, 2007-08 and 2017-18 was due to massive flood throughout the country, while in 1994-95, it was due to crisis in fertilizer. Our forecasting results show that the highest rice deficit would be 391 thousand metric tons in 2019-20 which is much lower than the deficit amounts that caused price hike before. On the other hand, Bangladesh produced surplus amount of rice estimated as 292 thousand metric tons in 1980-81, 186 thousand metric tons in 1989-90, 112 thousand metric tons in 1991-92 and 128 thousand metric tons in 2000-01 but the price of rice was stable on those years.

At the end, based on previous evidence, we may conclude that forecasted deficit amount of rice production in Bangladesh in future would not be a threat for price hike. The government, however, should be careful about massive flood pattern which showed up after every 10 years interval in Bangladesh. Government can minimize the production loss by developing early warning system of flood and further can recover the production loss quickly through providing input subsidy, interest free loan and extension services to the farmers after any natural calamities. The government can also closely monitor the rice market and demand and supply situations regularly to prevent any artificial crisis. Furthermore, government can ensure sufficient stock of rice for at least next 3 months to avoid any sudden crisis. Besides, the forecasted surplus amounts are not large enough in ARIMA and Holt-Winter approaches to decrease the price significantly. However, double exponential method shows large amount of rice surplus in the long-run for which the government should have preparation to utilize the surplus amount properly keeping the domestic price stable.

4.8 Summary and Conclusion

Rice is the single most important crop in Bangladesh which contributes to the economic and social welfare of the country through its positive influence on GDP, employment generation and attaining food security. Majority of the population (65%) in Bangladesh lives in rural area and their live and livelihood mostly depends on rice farming (World Bank 2017). In one hand, price of rice boosts up during low production due to inelastic demand of rice and affects the livelihood of most of the people. On the other hand, price of rice falls when there is a surplus in production and affects the farming community seriously since rice farming is the major source of income of them. Forecasting is an important and useful tool for price stabilization through balancing between demand and supply. Policy makers, researchers can find out important information from forecasting results to formulate effective policies on agricultural production, consumption, price stabilization and import and export decisions. Thus considering the importance of forecasting, this study attempted to forecast rice production and consumption by ARIMA, Holt-Winter and double exponential models to figure out the deficit or surplus production in Bangladesh in the short-run and the long-run up to year 2049-50.

We found ARIMA, Holt-Winter and double exponential models better performed in 5-year, 10-year and 20-year forecast horizon respectively based on out-of-sample forecast evaluation. The forecasting results by ARIMA and Holt-Winter approaches show that there might be deficit in rice production in Bangladesh both in the short-run and the long-run with few exceptions of surplus year at the end part of long-run. However, there might be surplus in rice production both in the short-run and the long-run based on double exponential approach. The deficits and surpluses are not too large to influence the price of the rice and a small amount of deficit production might be helpful for the farming community through stabilizing price.

Forecasting results might fluctuate due to forecasting error, massive natural calamities and for any other unseen reasons. Moreover, different forecasting models have different result and thus it is difficult to judge the best model. The policy maker should consider the results from different models before formulating any policy. The future research can address the factors of uncertainty in forecasting model and can also develop composite forecasting model based on several individual forecasting models.

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Chapter 5 - Overall Conclusion

Estimation of consumer demand for food has significant importance for Bangladesh to understand the changing consumption pattern due to change in different socio-economic factors and to evaluate the impact of rising food price on household welfare, food security and poverty matters. Based on demand estimation, policy makers can formulate policies on food security, health, nutrition, welfare and trade issues. However, policies on these issues cannot produce desired consequence without modelling the real phenomena of consumer behavior by an advanced demand model. The Exact Affine Stone Index (EASI) model of Lewbel and Pendakur in 2009 is a more refined approach to estimate consumer demand since it directly addresses the fundamental shortcomings of the AIDS and its family models by allowing for arbitrarily complex Engel curves where the slope of the curve is determined by the data, and provides sufficient flexibility for recognizing unobserved consumer heterogeneity. Further, GEASI, one of the family models of EASI can incorporates pre-committed demand which is widely observed phenomenon in the consumer behavior. This study applies both EASI and GEASI model to estimate consumer demand for food in Bangladesh accounting household heterogeneity, allowing flexibility of Engle's curve and addressing pre-committed demand. This study is a first empirical evidence to apply EASI and GEASI specification to the estimation of food demand structure in Bangladesh. The findings of the study provide strong empirical evidence for the presence of pre-committed demand for major food items in Bangladesh. Furthermore, the study provides an insight about future demand and supply situation of rice, the most important crop in Bangladesh. The empirical findings on the structure of food demand in Bangladesh can contribute formulating policy decisions in light of ongoing socio-economic change in the country.