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Analyses of Aggregate Food Demand in the United States

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Abstract This study applies the Almost Ideal Demand System (AIDS) to estimate consumers demand for 9 major aggregate food items in the United States using household survey data from January 1959 to February 2016. More specifically, consumers' price and expenditure sensitivity of demand was examined for cereals and bakery products; meats and poultry; fish and seafood; milk, dairy products and eggs; fats and oils; fresh fruit and vegetables; processed fruits and vegetables; sugar and sweets; and other foods. The empirical results illustrate that the consumption pattern of U.S. households has been changed significantly over the past 30 years. Although meats and poultry have the largest expenditure share but show a decreasing trend over the study period. Whereas, expenditure shares for processed fruits and vegetables, sugar and sweets, fats and oils, fish and sea exhibit very small changes. The compensated own price elasticities indicate that all food items are price inelastic having elasticities between -0.25 to -0.78. The compensated cross price elasticity estimates show that cereals and bakery products is a significant substitute of meats and poultry, fats and oil, and fresh fruits and vegetables but complement to fish and seafood, and processed fruits and vegetables. Expenditure elasticities of all goods are positive indicating all food categories are normal goods. The findings of the study would be helpful for the policy makers and agribusiness market participants to formulate effective policies and strategies for the improvement of consumers' as well as producers' welfare.

Keywords: *food demand, AIDS model, expenditure elasticity, price elasticity, cross price elasticity*

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1. Introduction

Consumer demand for food is an important parameter to policy makers and agribusiness market participants to decide on food and business policies. Since the demand for food is in general inelastic and production or supply somewhat variable, accurate estimation of demand parameters is important for the development of national price stabilization, trade, storage, production and other policies [1]. The first and foremost duty of any government is to ensure uninterrupted supply of food at reasonable price through the year round for meeting the demand of consumers as food is the most basic needs of human being. The United States has an advanced food distribution system that causes lower food prices similar to other high-income countries, one consequence of this is that food insecurity rates are lower than developing countries [2]. However, fluctuation of agricultural production accompanied with recent trade war between the United States and China, raise concerns of the policy makers in USA about the capability of local agricultural production to meet future demand [3]. To estimate future demand for different food items, estimation of price and income elasticities by analyzing consumer demand is necessary [4,5,6]. Hence, this study attempts to analyze consumer demand for major aggregate food items in the United States.

Consumer demand for food is a potential component of the structure within which the agricultural sector should be operated. In any planned and systematic economic development program, exchange of goods assumes a very important role in maintaining a balance between production and consumption. Information on present and future food pattern and how they are likely to change as price and income change is required to assess welfare and distribution impacts of technological change, infrastructure development and economic policies [7]. Consumers' demand for food in USA is changing due to several economic and demographic factors including increase in per capita income, price, population and urbanization, health concerns, older population, women in work force etc. As a developed country average life span of U.S. people is very high. According to [8] the fraction of the population that is 65 years old or greater is 13% and is expected to reach 20% by 2050. At the same time, Centers for Disease Control and Prevention (CDC) reported that

69% of U.S. adults are overweight or obese [9]. As a result, there are greater concerns about health among the older and obese as well as other people in USA which leads to change in food preferences specially preferences towards healthier foods. Consumers' are more concern to lose weight and thus consumers' preferences are shifting from more caloric food items to less caloric, and nutritious food items [10]. Additionally, both men and women are participating in work force increasingly and also households are working longer time than before. This creates change in food demand and preferences, consumers are shifting their preferences from traditional food to convenient foods such as processed meats, fruits and vegetables, ready-to-eat meals that can be served for the family members. Furthermore, changes in preferences due to changes in taste, lifestyle and occupation structure are also triggering the change in food demand structure. Thus, a clear understanding of the distributions of changing price and expenditure elasticities for major food items is crucial for the policy makers to ensure food balance in the country.

Almost Ideal Demand System (AIDS) model is a widely used model in estimation of demand for different food items in different countries of the world. For example, [11] used AIDS model to estimate the demand of North American fresh tomato, [12] estimated the demand of meat in Greece, [13] investigated demand of fresh fruit in Portugal, [14] explored demand of food in Switzerland, [15] estimated demand for meat in Bangladesh using the AIDS model. Significant scholarly contributions have been made in the literature for demand analysis of specific food items in USA. Consider for instance, [16-20]. [21] investigated demand for beef and chicken products with weak separability and structural change. Test of weak separability indicates that consumers prefer different meat products than meat aggregates such as beef or chicken. Test of structural change also shows shift in preferences from beef towards chicken. [17] modeled the pattern of structural change in U.S. meat demand and found that structural change partly explained the observed U.S. meat consumption pattern. [19] examined demand for fluid milk product in the U.S. and showed that the demand for fluid milk products has changed dramatically in recent years not only in terms of lower levels consumed but also in terms of the composition of the products consumed. [20] estimated pre-committed beef, pork, poultry and fish demand by U.S. and Japanese households employing the GAIDS model. The study reveals 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. Few empirical studies have developed a complete demand system for food commodities in the United States. Two notable examples are [22] and [23] who applied a synthesis approach to generate a demand system.

Above studies indicates that little work has been done to evaluate a detailed anatomy of food products elasticity and there is no recent research work on estimation of food demand elasticities in the United States. However, consumer taste and preference are always changing and these can affect the consumer purchasing behavior. Changes in prices and income can also lead to changes in purchasing behavior of consumer that can be predicted by elasticity estimates. Thus, the main objective of this study is to estimate price and expenditure elasticities of major aggregate food items in USA using AIDS model.

2. Materials and Methods

2.1. Data

National monthly per capita food consumption expenditures and price indices corresponding to each expenditure categories have been collected from January 1959 to February 2016 from the Bureau of Economic Analysis (BEA). The data include expenditure and price on major aggregate food items like cereals and bakery products, meats and poultry, fish and seafood, milk, dairy products and eggs, fats and oils, fresh fruit and vegetables, processed fruits and vegetables, sugar and sweets, other foods. Tables 1 present the summary statistics of personal consumption expenditures of 9 major food items in USA.

Table 1. Summary statistics of monthly personal consumption expenditure on major aggregate food items from January 1959 to February 2016

Food Category	Total no. of Obs.	Average expenditure (cents)	Std. Dev.	Min	Max
Cereals and bakery products	686	34523.5	198.1754	1	686
Meats and poultry	686	53597.84	40985.14	7511	136254
Fish and sea food	686	69113.07	42042.52	13573	159212
Milk, dairy products and eggs	686	6172.87	3791.27	981	13537
Fats and oils	686	35489.66	21309.83	9794	81106
Fresh Fruit and Vegetables	686	7970.52	4705.23	1548	17198
Processed fruits and vegetables	686	29895.19	23378.5	5436	82732
Sugar and sweets	686	13729.85	7384.69	2408	27920
Other foods	686	20499.54	12379.68	3151	42768

Source: Bureau of Economic Analysis (BEA), 2016 [24].

It is evident from Table 1 that consumers spent the highest amount of money on purchasing fish and sea foods followed by meats and poultry and cereals and bakery products. On the other hand, consumer spent the lowest amount of money in purchasing milk, dairy products and eggs. Furthermore, consumers in USA spent a significant amount of money on fats and oil, and processed fruits and vegetables.

Table 2. Summary statistics of price indices of major aggregate food items from January 1959 to February 2016

Food Category	Total no. of Obs.	Average Prices (cents/unit)	Std. Dev.	Min	Max
Cereals and bakery products	686	53.43	30.14	15.12	109.43
Meats and poultry	686	60.52	30.19	19.40	126.68
Fish and seafood	686	55.20	33.28	10.83	121.81
Milk, dairy products and eggs	686	59.21	30.91	17.89	120.30
Fats and oils	686	57.84	29.70	17.64	116.35
Fresh Fruit and Vegetables	686	54.71	31.33	12.74	113.04
Processed fruits and vegetables	686	53.81	28.86	15.89	107.22
Sugar and sweets	686	55.99	31.52	12.49	110.79
Other foods	686	57.11	30.93	16.58	110.05

Source: Bureau of Economic Analysis (BEA), 2016 [24].

2.2. Empirical Framework

The Almost Demand System (AIDS) of [25] is popular and extensively used model in the estimation of consumer demand due to being consistent with theory which satisfy budget constraints and the axioms of order, aggregate over consumers without invoking parallel linear Engle curves, and have approximate versions that can be estimated by linear regression. Our empirical model is based on Almost Ideal Demand System (AIDS) presented by [25]. In this study, Linear Aggregation to the general form of AIDS model with time trend is given below:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln\left(p_j\right) + \beta_i[\ln\left(\mathrm{X}\right) - \ln\left(\mathrm{P}\right)] + \delta_i t \forall i \quad (1)$$

Where w_i is the budget share of the ith good. p_j denotes prices and X is total expenditure on all goods. P is the price index and defined as:

$$\ln P = \alpha_0 + \sum_i \alpha_i \ln p_i + 0.5 \sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j \quad (2)$$

The restriction on this demand function are listed below: Adding up restriction:

$$\sum_i \alpha_i = 1, \sum_i \gamma_{ij} = 0, \sum_i \beta_i = 0, \sum_i \delta_i = 0. \quad (3)$$

Homogeneity restriction:

$$\sum_i \gamma_{ij} = 0 \quad (4)$$

Symmetry restriction:

$$\gamma_{ij} = \gamma_{ji}. \quad (5)$$

We estimated the linear approximation to the AIDS model (LA-AIDS) in differences with a time trend:

$$\Delta w_i = \delta_i + \sum_j \gamma_{ij} \cdot \Delta\ln\left(p_j\right) + \beta_i \Delta\ln\left(\frac{X}{P}\right) \forall i \quad (6)$$

We estimate the model for aggregate food products using iterative Zellner's seemingly unrelated regressions. Due to adding up restriction other foods (not classified elsewhere) equation was dropped. The intercept in the equation (6) indicates the exogenous gradual growth or decline in the budget share of good i.

3. Results and Discussion

The consumption pattern of U.S. households has been changed significantly over the past 30 years. Figure 1 presents a time series graph of expenditure share for aggregate food products. Meat and poultry enjoy the largest expenditure share. However, over time we observe a decline in spending share on this category. Whereas, expenditure shares for processed fruits and vegetables, sugar and sweets, fats and oils, fish and sea foods remained less than 10 percent and exhibit very small changes. The expenditure share of milk dairy product and eggs declined from 20 percent in 1959 to around 10 percent in 2016. The spending share on other foods (not classified in any category) increased significantly from less than 10 percent in 1959 to around 20 percent in 2016.

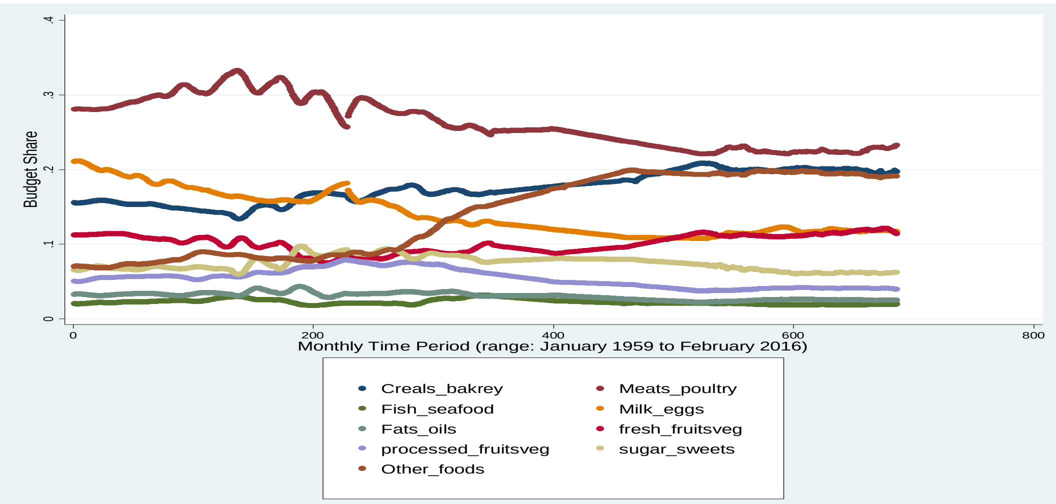

Figure 1. Time series plot of budget shares for aggregate food categories

Results for aggregate models are presented in Table 3 and Table 4 respectively. The coefficient estimates in Table 3 seem to be reasonable. In addition, coefficients are mostly significant. The intercept in each equation allows for the exogenous growth or decline in the share of each food category. It is equivalent to time trend in the static model. We can use these intercepts to discuss the evidence of structural change in aggregate model. In the aggregate model, the intercept is significant for all food categories indicating gradual growth or decline in the share of these food categories independent of relative price movements. The intercept is negative for cereals and bakery products and fresh fruits and vegetables, and positive for rest of the food categories. Intercept of the aggregate meat and poultry equation indicates that the budget share of this group has increased significantly over time. On the other hand, the aggregate equation for fresh fruits and vegetables indicate that expenditure share on this group has declined. In addition, the budget share of milk and dairy products have increased over time.

Table 4 present the expenditure elasticities and compensated own and cross price elasticities for food products under analysis. Compensated own-price elasticities are presented in the diagonal elements of Table 4. Own price elasticities of all of the food items except processed fruits and vegetables, and other foods were of appropriate sign, i.e., negative and also significant. The average own price elasticities for all aggregate groups are smaller in absolute value than their respective constituents. The compensated own price elasticities indicate that all food items are price inelastic having elasticities between -0.25 to -0.78. The estimates suggest that households were not so responsive to change in prices because firstly, in developed countries like USA, consumers spend a small share of total expenditure on food consumption that do not affect significantly with the change in price and secondly, the demand is also saturated. In general, the average own price response for each aggregate group is reduced by the substitution effect among the constituents of that particular group.

Table 3. Coefficient estimates for aggregate food model

Food category	Cereals and bakery products	Meats and poultry	Fish and seafood	Milk, dairy products and eggs	Fats and oils	Fresh fruits and vegetables	Processed fruits and vegetables	Sugar and sweets	Other foods	Expenditure	Intercept
Cereals and bakery products	**0.009** 0.005	**0.008** 0.004	**-0.012** 0.002	**-0.032** 0.004	**0.008** 0.002	**0.011** 0.003	**-0.064** 0.002	**0.008** 0.003	**0.064** 0.004	**0.078** 0.002	**-0.481** 0.020
Meats and poultry	**0.008** 0.004	**0.109** 0.006	**-0.014** 0.002	**0.014** 0.005	**0.001** 0.002	**-0.027** 0.004	**0.002** 0.002	**0.014** 0.003	**-0.108** 0.004	**-0.081** 0.003	**0.933** 0.025
Fish and seafood	**-0.012** **0.002**	**-0.014** 0.002	**0.006** 0.001	**0.004** 0.002	**-0.006** 0.001	**-0.004** 0.002	**0.024** 0.001	**-0.005** 0.001	**0.007** 0.002	**-0.010** 0.001	**0.106** 0.009
Milk, dairy products and eggs	**-0.032** 0.004	**0.014** 0.005	**0.004** 0.002	**0.078** 0.008	**-0.009** 0.002	**0.026** 0.004	**0.018** 0.003	**-0.027** 0.003	**-0.072** 0.005	**-0.100** 0.003	**0.974** 0.024
Fats and oils	**0.008** 0.002	**0.001** 0.002	**-0.006** 0.001	**-0.009** 0.002	**0.013** 0.002	**-0.015** 0.001	**0.027** 0.002	**0.012** 0.001	**-0.031** 0.002	**-0.010** 0.001	**0.113** 0.008
Fresh fruits and vegetables	0.011 0.003	**-0.027** 0.004	**-0.004** 0.002	**0.026** 0.004	**-0.015** 0.001	**0.048** 0.004	**-0.019** 0.002	**-0.050** 0.003	**0.030** 0.003	**0.016** 0.002	**-0.028** 0.020
Processed fruits and vegetables	**-0.064** 0.002	**0.002** 0.002	**0.024** 0.001	**0.018** 0.003	**0.027** 0.002	**-0.019** 0.002	**0.051** 0.003	**0.015** 0.002	**-0.056** 0.002	**-0.035** 0.001	**0.341** 0.011
Sugar and sweets	**0.008** 0.003	**0.014** 0.003	**-0.005** 0.001	**-0.027** 0.003	**0.012** 0.001	**-0.050** 0.003	**0.015** 0.002	**0.051** 0.003	**-0.017** 0.003	**-0.011** 0.002	**0.170** 0.015

Note:
1) Underlined coefficient estimates are not significant at 5% level
2) The coefficient estimates are reported in bold font and corresponding standard errors are provided below each coefficient
3) The intercept for Food products not elsewhere classified is -2.26

Table 4. Compensated price and expenditure elasticity estimates for aggregate food model

Food Category	Cereals and bakery products	Meats and poultry	Fish and seafood	Milk, dairy products and eggs	Fats and oils	Fresh fruits and vegetables	Processed fruits and vegetables	Sugar and sweets	Other foods	Expenditure
Cereals and bakery products	-0.776	0.310	-0.046	-0.042	0.076	0.163	-0.310	0.118	0.506	1.445
Meats and poultry	0.207	-0.324	-0.031	0.194	0.036	0.000	0.063	0.127	-0.271	0.689
Fish and seafood	-0.351	-0.361	-0.697	0.308	-0.218	-0.075	1.124	-0.167	0.438	0.571
Milk, dairy products and eggs	-0.053	0.361	0.050	-0.307	-0.031	0.283	0.184	-0.116	-0.372	0.289
Fats and oils	0.438	0.306	-0.162	-0.141	-0.544	-0.403	0.933	0.454	-0.880	0.681
Fresh fruits and vegetables	0.282	-0.001	-0.017	0.395	-0.122	-0.423	-0.132	-0.418	0.435	1.154
Processed fruits and vegetables	-1.002	0.307	0.473	0.479	0.526	-0.246	0.000	0.361	-0.897	0.362
Sugar and sweets	0.278	0.448	-0.051	-0.219	0.186	-0.566	0.262	-0.247	-0.091	0.848
Other foods	0.636	-0.511	0.072	-0.376	-0.193	0.315	-0.348	-0.049	0.453	0.285

Note: Underlined elasticity estimates are not significant at 5% level.

Cross price elasticity measures change in demand of one commodity due to a change in price of another related commodity [26]. Cross price elasticity indicates the relationship between the two products, whether the products are compliment or substitutes to each other. A negative cross price elasticity indicates complementary relationship between two commodities while positive cross price elasticity indicates that the two products are substitutes. The estimated cross-price elasticities as shown in the off-diagonal entries of the Table 4 may reflect the consumers' view of substitute or complement relations of certain price changes. The compensated elasticity estimates indicate that cereals and bakery products is a significant substitute of meats and poultry, fats and oil, and fresh fruits and vegetables but complement to fish and seafood, and processed fruits and vegetables. On the other hand, meat and poultry is found to be a significant substitute for milk, dairy products and eggs, fats and oil, fresh fruits and vegetables, processed fruits and vegetables, and sugar and sweets. The cross price substitution effect between the meats and poultry group is significant. Similarly, the cross price substitution is significant and large for all categories in milk and dairy products and fresh fruits and vegetables. We can use the separability tests to understand how consumers allocate the food budget among different food products.

Expenditure elasticity measures the responsiveness of consumer demand due to change in expenditure and the degree of necessity of the good (the more necessary good, the lower the income elasticity of demand) [27]. A commodity can be classified as superior, inferior, necessity or luxury depending on the degree of fluctuation of demand with a change in the income. The estimated expenditure elasticities are shown in the Table 4. The result shows that expenditure elasticities of all goods are positive indicating all food categories are normal goods. Cereals and bakery products, fresh fruits and vegetables are found to be expenditure elastic and while meats and poultry, fish and seafood, milk, dairy products and eggs, fats and oils, fresh fruits and vegetables, processed fruits and vegetables, sugar and sweets, and other foods are expenditure inelastic meaning necessary commodities. Additionally, expenditure elasticities of all food commodities are significant.

4. Conclusion

In this study an attempt has been made to estimate the demand elasticity of 9 major aggregate food items in terms of price and expenditure. We used almost ideal demand systems for aggregate food categories in the United States using monthly time series data ranging from January 1959 to February 2016. The intercept is found to be significant for all food items indicating gradual growth or decline in the share of these food categories. The intercept is negative for cereals and bakery products and fresh fruits and vegetables while positive for rest of the food categories. Intercept of the aggregate meat and poultry equation indicates that the budget share of this group has increased significantly over time. Gradual decline in the budget share of fresh fruits is responsible for decline in overall budget allocated to fresh fruits and vegetables while the budget share of meat and poultry has increasing showing positive intercept in their equation. Own price elasticities of all of the food items except processed fruits and vegetables, and other foods are estimated to be negative, inelastic and also significant. The average cross price elasticities between aggregate groups are affected by strong cross price effects between the constituents of these groups. Additionally, expenditure elasticities of all goods are positive indicating all food categories are normal goods.

The demand estimation models provide information on the ways in which consumers respond to the changes in prices, income and socio-demographic circumstances. Once the demand model parameters and mainly the demand elasticities for the different groups of food products are identified, more sophisticated evaluations are also possible, for instance evaluations of supply shocks or of the effects of certain food policy interventions, eventually targeting certain demographic groups. A household’s consumption is attributed by its own price, cross price, income and other factors depending on the nature of commodity and particular aims of the investigation were not considered in the above studies. Investigation of changes in demographic characteristics of U.S. society may help to identify the sources of consumer preference shifts over time. In addition, there is a need to conduct separability tests to understand how consumers allocate their food budget into different food products.

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