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Estimating Rural Household Food Demand in Iran Using the QUAIDS Model: Insights for Policy Design

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Abstract

Food security, as a key pillar of sustainable development and social welfare, is particularly sensitive to price fluctuations and income volatility in rural communities. In Iran, recent inflationary pressures and declining household purchasing power have highlighted the need for a scientific analysis of food demand patterns and the evaluation of policy interventions. This study aims to provide a policy-oriented analysis of food demand patterns among rural households in Iran and to assess the potential impacts of alternative policy interventions. Data were drawn from the 2023 Household Income and Expenditure Survey, and the Quadratic Almost Ideal Demand System (QUAIDS) was employed to estimate consumption patterns while accounting for theoretical constraints and household demographic characteristics. Eight main food groups—cereals, proteins, dairy, oils and fats, fruits and nuts, vegetables and legumes, sugar and confectionery, and spices and beverages-were analyzed. Results indicate that cereals and proteins function as necessities with low income and price elasticities, whereas vegetables and legumes exhibit more luxury-like characteristics, with consumption increasing at higher income levels. Cross-price elasticities reveal both substitution and complementarity among food groups, providing important insights for the design of pricing and fiscal policies. Demographic factors, including household size, education, and age, significantly influence consumption patterns. Welfare analyses further show that low-income rural households are the most vulnerable to rising food prices. Overall, the findings not only corroborate previous domestic and international studies but also provide new evidence on the sensitivity of food demand to income and price changes in Iran. Based on the estimated income and own-price elasticities, the findings suggest that food subsidy reforms should focus on staple goods with low income and price elasticities to protect low-income rural households, while targeted income support and price stabilization policies are more appropriate for food groups exhibiting high income and own-price responsiveness, such as vegetables and legumes. Furthermore, the presence of significant cross-price substitution effects implies that price interventions in one food group may have spillover effects on the consumption of other foods, which should be considered in policy design.

Keywords: Food demand, Food security, Price and income elasticities, QUAIDS model, Rural areas

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Introduction

Food security, as one of the fundamental pillars of sustainable development, social welfare, and economic stability, has increasingly drawn the attention of researchers and policymakers over the past two decades (FAO, 2022; World Bank, 2023). This challenge is especially pressing given that, in 2022 alone, more than 735 million people worldwide experienced hunger-a majority of them in developing countries and rural areas (WFP, 2023). Global crises such as the COVID-19 pandemic, the war in Ukraine, and the impacts of climate change have further disrupted supply chains, fueled sharp increases in food prices, and limited the access of vulnerable groups to essential goods (Valera *et al.*, 2023; Dhar *et al.*, 2024).

Recent studies highlight that households across countries, particularly in developing economies, are vulnerable to price and income shocks, because they allocate a large share of their income to food purchases and face limited substitution possibilities when adjusting their consumption (Andreyeva *et al.*, 2010; Ansah *et al.*, 2022; Dhar *et al.*, 2024). Iran is no exception. Official statistics from the Statistical Center of Iran show that food price inflation reached approximately 40 percent in 2022–2023, substantially eroding households' real purchasing power. This sharp increase in food prices has been accompanied by a decline in the consumption of protein-rich and dairy products, with the adverse effects being particularly pronounced among low-income rural households (Statistical Center of Iran, 2023). Household Income and Expenditure Survey (HIES) data suggest that own-produced food accounts for a meaningful share of food consumption among rural households, indicating their reliance on home production as a coping mechanism against market price shocks. However, empirical evidence shows that existing subsidy and compensatory policies have not been sufficient to stabilize food access, particularly under high food inflation, leading to welfare losses among rural households (Falsafian *et al.*, 2024).

At both international and national levels, numerous studies have analyzed food demand patterns using the Almost Ideal Demand System (AIDS) and its quadratic extension Almost Ideal Demand System (QUAIDS). Mekonnen *et al.* (2012) applied QUAIDS to fruit consumption in the U.S., demonstrating the model's flexibility in capturing non-linear Engel relationships. Korir *et al.* (2018), using household data from Kenya, found that protein consumption is highly responsive to price fluctuations, whereas higher income promotes a more diversified diet. Ansah *et al.* (2022) further showed that, in addition to price and income effects, household characteristics such as size, head's education, and residence location significantly influence food consumption patterns. Forgenie *et al.* (2024) analyzed per capita food consumption in net food-importing developing countries, highlighting how price shocks can disproportionately affect nutrient intake among lower-income households. Most recently, Muiruri *et al.* (2025) demonstrated in Nairobi, Kenya, that staples such as cereals and bread have low price and income elasticities, while consumption of meat and dairy products is more sensitive to income changes.

Among domestic studies, Akbari *et al.* (2017) examined the food demand of urban households in Sistan and Baluchestan Province. Their findings indicated that items such as bread and cereals, milk and eggs, legumes and vegetables, sugar, and beverages are classified as necessities, while meat, oils and fats, fruits, and nuts were found to be luxury goods with higher income sensitivity. Ataie Solout & Mohammadi (2018), using time-series data from Mazandaran Province, estimated price and income elasticities of food groups and similarly identified bread, cereals, and vegetables as necessities, while meat and fruits exhibited luxury characteristics. Baghestany & Sherafatmand (2021), applying a threshold regression model, estimated supply and demand elasticities for tea in Iran and concluded that tea is a relatively inelastic commodity. Khalili Malakshah et al. (2021)

analyzed rural and urban households across Iran and found that household characteristics such as income, size, and demographic composition significantly shape food demand patterns. Specifically, rural households exhibited lower price and income elasticities for staple foods such as cereals and bread, whereas consumption of protein-rich and dairy products was more sensitive to income changes in urban households. These findings highlight the heterogeneity of consumption patterns across regions and underscore the need for a focused analysis of rural households to inform policy interventions. Falsafian *et al.* (2024) also assessed the impact of food tariff reforms on household welfare and reported that such reforms reduced welfare, particularly among low-income and rural households. In another study, Layani & Bakhshoodeh (2025) investigated the effects of rising global food prices on rural poverty and vulnerability in Iran, showing that price increases reduced welfare and heightened household vulnerability.

Taken together, international studies indicate that food demand in low-income societies is highly sensitive to changes in prices and incomes, particularly for staple foods (Andreyeva *et al.*, 2010; Korir *et al.*, 2018; Muiruri *et al*., 2025). These studies often focus on specific commodities, regions, or short-term price shocks, leaving gaps in nationwide, comprehensive analyses. In Iran, domestic studies have primarily focused on provincial or urban households and limited food groups (Akbari *et al*., 2017; Ataie Solout & Mohammadi, 2018; Khalili Malakshah *et al.*, 2021; Falsafian *et al.*, 2024), and often rely on outdated data or omit demographic heterogeneity and policy-relevant implications. By contrast, the present study provides a nationwide, up-to-date analysis of rural food demand using 2023 Household Income and Expenditure Survey data, estimates a complete QUAIDS-based demand system across major food groups, incorporates household demographic heterogeneity, and emphasizes policy implications including targeted subsidies, price stabilization, and income support.

Furthermore, although several national-level studies on food consumption in Iran exist, many of them suffer from important limitations. These include reliance on outdated data, focus on single commodities or partial food groups, and the use of reduced-form approaches that do not estimate a complete demand system consistent with economic theory. In addition, the majority of existing studies emphasize elasticity estimation without fully exploiting demand functions for policy design, such as evaluating differential price and income responses across food groups and household characteristics. As a result, there remains a need for a comprehensive, up-to-date demand system analysis that can provide policy-relevant insights into food security and welfare in rural Iran. In this context, estimating a theoretically consistent demand system is essential not only for obtaining reliable elasticity estimates but also for understanding substitution and complementarity patterns across food groups, which are critical for effective policy design. By employing the QUAIDS model and recent nationwide data, this study addresses key limitations of existing research and provides a solid empirical foundation for designing targeted subsidies, price stabilization policies, and income support programs tailored to rural households in Iran.

Accordingly, the present study employs the QUAIDS model with data from the 2023 Household Income and Expenditure Survey to provide an evidence-based picture of rural food consumption patterns in Iran. The main contribution of this study lies in providing an updated, nationwide analysis of rural food demand in Iran using 2023 Household Income and Expenditure Survey data. Unlike previous studies that often focused on specific provinces, limited food groups, or single elasticity estimation, this study simultaneously estimates a complete demand system within the QUAIDS framework, incorporates household demographic heterogeneity, and provides policy-oriented insights by examining both income and price elasticities, including substitution and complementarity effects among food groups. This approach allows for a

clearer understanding of how factors such as household size, education, gender, and age structure influence food demand, and supports the design of targeted subsidies, income support, and price stabilization policies.

The main objective of this study is to provide a comprehensive, nationwide analysis of rural food demand in Iran using 2023 Household Income and Expenditure Survey data, estimating a complete QUAIDS-based demand system, incorporating household demographic heterogeneity, and highlighting policy-relevant implications. By addressing gaps in previous domestic and international studies—such as limited coverage of rural areas, outdated data, or omission of demographic and policy considerations—this research aims to contribute both to the literature and to evidence-based policy design.

Material and Methods

Household food demand has been analyzed in the literature using a range of approaches, including single-equation models, Engel curve specifications, and complete demand systems such as the Almost Ideal Demand System (AIDS). While simpler models allow for elasticity estimation, they do not adequately capture substitution and complementarity across food groups. To address these limitations, this study employs the Quadratic Almost Ideal Demand System (QUAIDS), which extends the AIDS model by allowing for nonlinear Engel curves and greater flexibility in modeling household consumption behavior, making it particularly suitable for policy-oriented analysis in heterogeneous rural settings. This approach has been extensively applied in food demand studies across developing-country contexts, including China (Zhou & Herzfeld, 2015; Chen *et al.*, 2016), Pakistan (Hayat *et al.*, 2016), and Kenya (Korir *et al.*, 2018).

Empirical evidence suggests that QUAIDS, with its nonlinear specification, can accurately describe consumer behavior compared to linear demand systems (Mekonnen *et al.*, 2012; Sola, 2013). Additionally, this approach enables meaningful comparisons between Iran and international evidence. The QUAIDS model, originally proposed by Banks *et al.* (1997), extends the Almost Ideal Demand System (AIDS) of Deaton & Muellbauer (1980) by introducing a quadratic term of log-expenditure, which adds flexibility in modeling Engel curves. This feature is especially important when analyzing heterogeneous households, where income and demographic characteristics play a crucial role. The general QUAIDS specification for the budget share of the i-th food group can be expressed as:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} lnp_j + \beta_i \ln\left(\frac{X}{P}\right) + \frac{\lambda_i}{2}\left[\ln\left(\frac{X}{P}\right)\right]^2 + \epsilon_i \quad (1)$$

Where w_i denotes the expenditure share of group i, p_j is the price of group j, X is total household expenditure and P is the translog price index defined in Equation (2). The parameters $\alpha_i, \gamma_{ij}, \beta_i, \lambda_i$ are to be estimated, and ϵ_i denotes the error term. If $\lambda = 0$ the model reduces to the standard AIDS system.

$$\ln P = a_0 + \sum_{i=1}^{n} a_i \, lnp_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} lnp_i lnp_j \quad (2)$$

In order to account for household heterogeneity, demographic variables were included in the intercept term of the demand equations using the demographic translation method, as outlined by Pollak & Wales (1992) and Poi (2012). This approach enables the intercepts to adjust systematically based on household characteristics, effectively capturing demographic diversity in preferences (Pollak & Wales, 1992; Poi, 2012).

$$w_i = \alpha_{i0} + \sum_{m=1}^{M} \delta_{im} Z_m + \sum_{j=1}^{n} \gamma_{ij} lnp_j + \beta_i \ln\left(\frac{X}{P}\right) + \frac{\lambda_i}{2}\left[\ln\left(\frac{X}{P}\right)\right]^2 + \epsilon_i \quad (3)$$

where Z_m represents demographic characteristics such as household size, education, age, and gender of the household, as specified in Equation (3).

To ensure consistency with consumer demand theory, the adding-up and homogeneity restrictions are imposed following Deaton & Muellbauer (1980), and the symmetry restriction is imposed in line with standard demand theory (Pollak & Wales, 1992; Banks *et al.*, 1997).

Adding-up

$$\sum_{i=1}^{n} \alpha_i = 1\,, \quad \sum_{i=1}^{n} \beta_i = 0\,, \quad \sum_{i=1}^{n} \lambda_i = 0\,, \quad \sum_{i=1}^{n} \gamma_{ij} = 0 \; for \; all \; j \quad (4)$$

Homogeneity

$$\sum_{j=1}^{n} \gamma_{ij} = 0 \; for \; all \; j \quad (5)$$

Symmetry

$$\gamma_{ij} = \gamma_{ji} \; for \; all \; i,j \quad (6)$$

Based on the estimated QUAIDS parameters, income elasticities as well as uncompensated (Marshallian) and compensated (Hicksian) price elasticities are computed using the standard formulas derived from demand theory. These expressions follow the original derivations in Banks *et al.* (1997) and their applied implementation as outlined in Poi (2012), and are reported in Equations (7)– (9).

$$\eta_i = 1 + \frac{\beta_i + 2\,\lambda_i \ln(\frac{X}{P})}{w_i} \quad (7)$$

$$e_{ij}^{U} = \frac{\gamma_{ij} - \beta_i\left(w_j + \lambda_i \ln\left(\frac{X}{P}\right)\right) + \lambda_i\, w_j \ln\left(\frac{X}{P}\right)^2}{w_i} \quad (8)$$

$$e_{ij}^{C} = e_{ij}^{U} + w_j \eta_i \quad (9)$$

The demand system was estimated as a set of equations using an iterated Seemingly Unrelated Regression (SUR) procedure, which accounts for contemporaneous correlation across equation error terms and improves estimation efficiency. The implementation follows the methodological framework described in Poi (2012). The following subsection describes the data source and construction of food groups used for estimating the demand system.

Data

The data used in this study were drawn from the 2023 Household Income and Expenditure Survey (HIES) conducted by the Statistical Center of Iran. The dataset provides detailed information on household food expenditures as well as demographic characteristics. After excluding missing observations, the final sample consists of 18,138 rural households. The survey contains information on approximately 230 food items. However, estimating demand equations for each item separately is practically infeasible. Therefore, in line with the standard coding system employed by the Statistical Center of Iran, individual food items were aggregated into eight main categories: (i) bread and cereals, (ii) proteins (meat, poultry, and fish), (iii) dairy products, (iv) oils and fats, (v) fruits and nuts, (vi) vegetables and legumes, (vii) sugar, sweets, and confectionery, and (viii) spices and beverages.

Results and Discussion

Characteristics of Rural Households (HIES 2023)

Table 1 presents the descriptive statistics of the 18,138 rural households included in this study. On average, households consist of 3.34 members, with the household head being 54.34 years old and having an average education level of 3.1, corresponding roughly to lower secondary education. The majority of household heads are male (≈84%). Monthly per

capita income averages 117.5 million IRR, while monthly per capita food expenditure averages 35.3 million IRR, indicating that households spend a substantial share of their income on food. These statistics provide an overview of the sample and set the stage for interpreting the subsequent empirical results on food demand patterns.

Table 1- Sample characteristics of rural households (HIES 2023)

Variable	Mean	Standard deviation	Min	Max
Household size	3.34	1.52	1	16
Household age	54.34	15	15	99
Household education (1 = illiterate; 2 = primary; 3 = lower secondary ;4= upper secondary/pre-university; 5 = associate; 6 = bachelor's ;7= master's; 8 = PhD+)	3.1	2.8	1	8
Gender (1 = male; 2 = female)	1.16	0.37	1	2
Monthly per capita income (million IRR/person)	117.5	143.7	5	1324.2
Monthly per capita food expenditure million IRR/person)	35.3	26.3	5	835.6

Estimation of the QUAIDS Model

Before estimating, the theoretical restrictions of the demand system- adding-up, homogeneity, and symmetry - were tested and imposed. The results confirmed that these conditions were not violated, ensuring the reliability of the final estimates. Moreover, a likelihood ratio (LR) test was conducted to assess the significance of the quadratic income term in the QUAIDS specification. A likelihood ratio (LR) test supported the inclusion of the quadratic income term, providing empirical justification for the use of the QUAIDS specification rather than the standard linear AIDS model. Therefore, the QUAIDS model was retained for the subsequent analysis of food demand among rural households in Iran.

Table 2 reports the estimated QUAIDS parameters for the eight food groups considered in this study. The expenditure coefficients (β), quadratic expenditure terms (λ), and cross-price parameters (γ) provide insights into the expenditure responsiveness, nonlinear demand behavior, and substitution or complementarity relationships among food groups.

The expenditure coefficients (β) highlight the responsiveness of budget shares to changes in total food expenditure. The negative and significant β for proteins implies that their budget share decreases as total expenditure rises, suggesting that rural households treat proteins as necessities. In contrast, vegetables and legumes show a positive and significant β, indicating luxury-type behavior at higher expenditure levels. This finding is consistent with Seale *et al.* (2003), who observed that dietary diversification toward vegetables increases with income growth in developing countries.

The quadratic terms (λ) capture nonlinear expenditure effects and allow Engel curves to deviate from the linear form imposed by the AIDS model. In this study, a positive and significant λ for cereals and proteins indicates that their budget shares increase at an accelerating rate as total household expenditure rises, reflecting convex Engel curves and highlighting the essential nature of these food groups. In contrast, negative and significant λ for oils and vegetables suggest that their budget shares increase at a decreasing rate or even decline at higher expenditure levels, indicating saturation effects. These results further confirm the relevance of accounting for nonlinear Engel curves in rural food demand analysis. Similar nonlinear effects have been reported in QUAIDS applications for developing-country contexts. For example, Korir *et al.* (2018) report non-linear Engel relationships in Kenya, and Ansah *et al.* (2022) apply QUAIDS in a Sub-Saharan Africa context and show that quadratic income terms help capture household heterogeneity.

Finally, the cross-price parameters (γ) reveal substitution and complementarity among food groups. For instance, cereals and proteins exhibit a positive and significant relationship, indicating substitution, while proteins and oils, as well as fruits and oils, show negative and

significant coefficients, reflecting complementarity. Dairy and vegetables, on the other hand, appear to be substitutes.

These results resonate with Zhou & Herzfeld (2015) for urban China, who document substitution and complementarity patterns in a dynamic demand framework. Cross-country analyses such as Forgenie *et al.* (2024) document heterogeneous per-capita consumption patterns across net food-importing developing countries, but do not directly estimate cross-price elasticities; therefore, cite Forgenie for cross-country patterning rather than as direct evidence of substitution/complementarity.

The estimated coefficients indicate that rural Iranian households consider proteins and cereals as necessities, while vegetables and legumes exhibit luxury-like characteristics, reflecting specific local consumption patterns. Additionally, the cross-price effects reveal notable substitution and complementarity relationships, such as between cereals and proteins or oils and fruits, which have not been explicitly documented in prior studies on rural Iran. These insights provide practical guidance for designing targeted price and subsidy interventions to improve rural dietary outcomes.

Effects of Demographic Characteristics on Food Budget Shares

Table 3 presents the effects of demographic characteristics on the budget shares of different food groups in rural Iran. The results suggest that the impacts of these variables are heterogeneous across food categories, with both the sign and magnitude of the coefficients varying by commodity groups. Coefficients in Table 3 represent the marginal effect of a one-unit change in each demographic variable on the corresponding food budget share. Although numerically small due to variable scaling, these effects are statistically significant, reflecting precise estimation enabled by the large sample size.

It should be noted that conventional goodness-of-fit measures such as R^2 or RMSE are not reported for individual equations, as they are less informative in the context of QUAIDS demand systems estimated jointly under adding-up constraints. Model reliability is assessed via system log-likelihood and the statistical significance of coefficients. Potential heteroskedasticity and cross-equation correlations are accounted for through the SUR estimation procedure, following standard practice in the literature.

Household size tends to increase the budget share of dairy, oils, vegetables, and legumes, indicating that larger households allocate relatively more of their food budget to these groups. This pattern is consistent with evidence from developing-country demand studies, where larger households face tighter per capita budget constraints that lead to relatively lower budget shares for higher-cost food groups (Andreyeva *et al*., 2010; Seale *et al.*, 2003). The estimated coefficients for demographic characteristics are numerically small because they represent the marginal effect of a one-unit change in the demographic variable on food budget shares. Despite their small magnitude, these effects are statistically significant due to the large sample size, which provides high statistical power. Therefore, the results reflect realistic incremental effects in the population rather than spurious significance. Moreover, demand analysis literature highlights the role of demographic structure - such as household size - in shaping consumption patterns through economies of scale and intra-household allocation (Pollak & Wales, 1992; Casado *et al.*, 2024). Recent QUAIDS-based evidence from rural Asia also shows that food demand shifts toward staple or lower-cost items as household size increases (Phetcharat & Chinnakum, 2022). These findings suggest that budget constraints and demographic factors help explain the observed negative relationship between household size and budget shares for certain food groups.

Table 2- Estimated QUAIDS coefficients for rural households in Iran

Coefficient	Bread & Cereals	Proteins	Dairy products	Oils & fats	Fruits & nuts	Vegetables & legumes	Sugar, sweets, and confectionery	Spices & beverages
α	0.044 (0.037)	0.189* (0.048)	0.196* (0.018)	0.161* (0.019)	0.119* (0.024)	0.152* (0.023)	0.068* (0.019)	0.071* (0.015)
β	0.016 (0.015)	−0.050* (0.018)	−0.011 (0.007)	0.000 (0.007)	0.001 (0.009)	0.042* (0.008)	−0.001 (0.007)	0.003 (0.007)
λ	0.006* (0.002)	0.006* (0.002)	−0.001 (0.001)	−0.003* (0.001)	0.002*** (0.001)	−0.007* (0.001)	−0.001 (0.001)	−0.003* (0.001)
γ_1	0.026** (0.012)							
γ_2	−0.078* (0.012)	0.095* (0.022)						
γ_3	0.018* (0.005)	−0.014*** (0.007)	0.004 (0.005)					
γ_4	0.088* (0.006)	−0.018*** (0.010)	0.012** (0.005)	0.066* (0.010)				
γ_5	−0.021* (0.007)	0.016*** (0.010)	−0.011** (0.005)	−0.102* (0.007)	0.095* (0.010)			
γ_6	−0.046* (0.006)	−0.018*** (0.009)	0.028* (0.005)	−0.009 (0.006)	0.025* (0.007)	0.053* (0.008)		
γ_7	0.013** (0.006)	0.023* (0.008)	−0.022* (0.005)	−0.034* (0.007)	−0.008 (0.006)	−0.031* (0.006)	0.076* (0.009)	
γ_8	0.000 (0.005)	−0.005 (0.007)	−0.014* (0.003)	−0.002 (0.005)	0.006 (0.005)	−0.002 (0.004)	−0.017* (0.005)	0.040* (0.005)

Notes: Standard errors are reported in parentheses. Coefficients represent the estimated effect of explanatory variables on household budget shares for each food group. Asterisks denote the level of statistical significance (*: $p < 0.01$, **: $p < 0.05$).

Education is associated with lower shares for bread and cereals and oils, while it significantly increases the shares of proteins and fruits and nuts. This finding is consistent with the literature (e.g., Ogundari & Abdulai, 2013), which shows that education improves nutritional awareness and shifts consumption away from inexpensive, carbohydrate-rich, or high-fat foods toward more diverse and healthier products. Thus, education plays a crucial role in dietary upgrading in rural areas.

Gender effects are statistically significant only for bread and cereals (positive) and proteins (negative), suggesting that households with different gender compositions may vary in their allocation to staple foods. However, no significant gender differences were observed for most food groups, implying that gender per se is less influential compared to structural and economic factors in shaping rural food demand.

Age is positively associated with bread but negatively related to dairy and proteins. This pattern indicates that older households tend to maintain traditional diets centered around bread, while reducing consumption of protein-rich and dairy products, possibly due to health considerations or life-cycle changes in preferences.

Overall, the findings highlight the heterogeneous role of demographic factors in shaping food demand. Household size tends to reduce the budget share of costly or traditional goods while increasing that of cheaper or more adaptable foods. Education fosters a shift toward higher-value and nutritionally superior items. Gender effects are limited to core staples, whereas age reflects life-cycle consumption adjustments. These results align with studies from other developing countries, underscoring the importance of incorporating demographic heterogeneity into food policy design aimed at improving nutrition and food security in rural Iran.

Expenditure Elasticities of Food Groups

Table 4 presents the expenditure elasticities of major food groups in rural Iran. The findings suggest that most food groups have elasticities close to unity, indicating that food items in rural households are considered essential. In other words, even when income falls, households strive to maintain consumption of basic food items.

It should be noted that expenditure elasticities for staples such as bread and cereals (1.086) and oils (1.005) slightly exceed unity. This reflects both quantity and quality upgrading as household total food expenditure increases, and these estimates are derived using real expenditure and normalized budget shares within the QUAIDS framework. Such magnitudes are consistent with prior evidence from rural settings and are plausible within the QUAIDS framework. However, there is some variation among commodity groups. Vegetables and legumes have the highest expenditure elasticity 1.29, categorizing them as luxury goods. Although this classification is consistent with observed dietary diversification in Iran, in many developing countries vegetables are typically categorized as necessities, suggesting that local dietary preferences and price structures strongly shape this pattern. This means that as income increases, households allocate more of their budget to fresh and diverse food items like vegetables, beans, and pulses. Meat, poultry, fish, and eggs (proteins) and dairy products show elasticities below one (0.82 and 0.87, respectively), confirming their role as core necessities in rural diets. Oils and fats and fruits and nuts both have elasticities of exactly 1.00, lying on the boundary between necessities and luxuries. Sugar, sweets, and confectionery (0.99) have a virtually unitary elasticity, while spices and beverages (0.71) are the least affected by income changes due to their small and stable budget share.

Table 3- Effects of demographic characteristics on food budget shares in rural Iran

Variable	Bread & cereals	Proteins	Dairy products	Oils & fats	Fruits & nuts	Vegetables & legumes	Sugar, sweets, and confectionery	Spices & beverages
Household size	−0.001***	−0.004*	0.002*	0.004*	−0.006*	0.003*	0.001*	0.001
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Household education (1 = illiterate; 2 = primary; 3 = lower secondary ;4= upper secondary/pre-university; 5 = associate; 6 = bachelor's ;7= master's; 8 = PhD+)	−0.006*	0.008*	0.000	−0.003*	0.004*	−0.002*	0.001*	−0.001***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Gender (1 = male; 2 = female)	0.017*	−0.015*	−0.002	−0.002	0.002	0.002	0.000	−0.002*
	(0.003)	(0.004)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
Household age	−0.001*	0.001**	0.000	0.000	0.000	0.000*	0.000*	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: Standard errors are reported in parentheses. Coefficients represent the estimated effect of demographic characteristics on household budget shares for each food group. Asterisks denote the level of statistical significance (*: $p < 0.01$, **: $p < 0.05$, ***: $p < 0.10$).

These results align with findings from other developing countries. Seale *et al*. (2003) found that most food groups in low- and middle-income countries are considered necessities with income elasticities close to one. Similarly, Kumar *et al*. (2011) estimated demand elasticities for food commodities in India and reported that cereals and other staples behave as necessities, while higher-value items such as fruits and animal products exhibit higher elasticities. Studies in countries like Kenya by Muiruri *et al*. (2025) show that staples like proteins and dairy are essential, while vegetables and fruits have higher elasticities, behaving more like luxury goods - similar to the trend observed in Iran. Mekonnen *et al.* (2012) applied QUAIDS to fruit consumption in the U.S., showing the flexibility of the model in capturing Engel curve non-linearities. In Sub-Saharan Africa, similar results are reported by Ansah *et al*. (2022) and Korir *et al*. (2018), where staple foods dominate household consumption, but as income rises, the consumption of higher-quality and more diverse items increases.

Overall, the expenditure elasticity results suggest that rural Iranian households view staple foods as necessities, but as incomes increase, there is a shift towards consuming more nutrient-rich and higher-quality foods, particularly vegetables and legumes. These findings imply that rural households prioritize staple foods but increase consumption of nutrient-rich items like vegetables and legumes as income rises. For policymakers, this suggests that income-support programs, targeted subsidies, or nutrition education initiatives can effectively encourage healthier diets. Specifically, policies could focus on increasing affordability and accessibility of vegetables and legumes, while maintaining support for staple foods to ensure food security. Additionally, complementary measures such as price incentives or awareness campaigns can guide households toward more balanced and diverse dietary choices, aligning with broader rural nutrition and health objectives.

Table 4- Expenditure elasticities of food groups in rural Iran

Food group	Bread & cereals	Proteins	Dairy products	Oils & fats	Fruits & nuts	Vegetables & legumes	Sugar, sweets, and confectionery	Spices & beverages
Expenditure elasticity	1.086*	0.819*	0.874*	1.005*	1.014*	1.286*	0.989*	0.706*
	(0.082)	(0.064)	(0.079)	(0.076)	(0.088)	(0.058)	(0.078)	(0.021)

Notes: Standard errors are reported in parentheses. Expenditure elasticities represent the responsiveness of household budget shares to changes in total food expenditure for each food group. Asterisks denote the level of statistical significance (*: $p < 0.01$).

Price Elasticities of Food Groups

Before discussing the elasticity results, it is important to clarify that the γ parameters reported in Table 1 are QUAIDS price coefficients rather than price elasticities. All own-price and cross-price elasticities are derived from these coefficients using standard QUAIDS formulas and are reported separately in Tables 5 (Marshallian) and 6 (Hicksian). Note that due to numerical approximations in deriving elasticities from estimated QUAIDS coefficients, cross-price elasticities may slightly violate symmetry (e.g., elasticity of cereals w.r.t. proteins ≠ elasticity of proteins w.r.t. cereals). These minor deviations do not affect the overall interpretation of substitution and complementarity patterns among food groups. The estimated uncompensated (Marshallian) and compensated (Hicksian) price elasticities for food groups in rural Iran reveal patterns largely consistent with theoretical expectations and international evidence. For bread and cereals, the Marshallian price elasticity is approximately -0.87, with the Hicksian elasticity slightly higher in absolute value. This indicates that price changes have limited impact on consumption, as bread and cereals are staple and essential items in rural households. Similar results have been documented in Iran and other developing countries (Falsafian *et al.*, 2024; Muiruri *et al.*,

2025). From a policy perspective, evidence from rural China (Wang *et al*., 2025) suggests that subsidies and support programs should prioritize staple foods to protect vulnerable households from the adverse effects of price fluctuations.

In contrast, spices and beverages show relatively low own-price elasticities (Marshallian ≈ -0.20; Hicksian ≈ -0.45), reflecting their small and stable budget share in rural households. Income effects on demand are minimal and consumers exhibit limited response to price changes for this group. Similar findings have also been reported in domestic studies, such as Khalili Malakshah *et al.* (2021), which estimate QUAIDS for Iranian rural and urban households and report patterns consistent with modest price responsiveness for several small-budget categories.

However, this pattern differs from some studies in South Asia and Africa that report higher price responsiveness for similar items (Andreyeva *et al.*, 2010; Muiruri *et al.*, 2025), underscoring the importance of context-specific consumption habits.

Animal-based products, such as dairy, show relatively high price elasticities (-0.946 Marshallian; -0.957 Hicksian), indicating that price increases can noticeably reduce consumption, although elasticities remain below unity in absolute terms. This pattern aligns with international evidence showing that animal-sourced foods are typically more price-sensitive than staple foods (Andreyeva *et al*., 2010). Policy implications include the need for targeted support, such as subsidies or income-based assistance, to protect low-income rural households from reductions in protein consumption.

Cross-price elasticities reveal additional insights. While some cross-price elasticities appear relatively large in magnitude, such values are not uncommon in rural and low-income settings, where households face tight budget constraints and limited substitution possibilities within narrowly defined consumption baskets. Negative relationships between the prices of spices/beverages and sugar, confectionery, or dairy indicate complementarity-for example, tea and beverages are often consumed with sweets or dairy products. These patterns are consistent with empirical evidence from Iran (Falsafian *et al.*, 2024) and suggest policy options such as taxation on sugary drinks, which could indirectly reduce sugar and confectionery consumption (Andreyeva *et al.*, 2010). Conversely, positive cross-price elasticities between spices/beverages and fruits/nuts suggest substitution, implying that households may shift toward healthier alternatives when prices rise, a trend also observed in other Asian contexts (Muiruri *et al*., 2025).

Overall, our elasticity estimates broadly align with international evidence: staple foods (cereals and proteins) are relatively price-inelastic, animal-sourced products tend to be more price-sensitive, and vegetables show higher income responsiveness (Seale *et al*., 2003; Andreyeva *et al*., 2010). Nevertheless, two empirical patterns deserve cautious interpretation. First, spices and beverages exhibit relatively low own-price elasticities in our rural sample (Marshallian ≈ −0.20; Hicksian ≈ −0.45), which contrasts with some studies reporting higher sensitivities for similar items. This discrepancy is plausibly explained by a combination of factors: cultural consumption patterns in Iran (e.g., habitual tea consumption that is relatively inelastic), the very small budget share and frequent purchase frequency of these items (which can dampen measured elasticities), and aggregation/price-measurement issues (grouping heterogeneous subitems or using area-level price proxies can bias elasticities toward zero). Second, the modest responsiveness observed for sugar and confectionery may partly reflect their complementarity with beverages (consumed together), household-level home production or transfers, and the particular way these items are grouped in the HIES data rather than true insensitivity to price. Taken together, these caveats affect the interpretation of specific cross-price relationships but do not alter the overall validity of the estimated demand system or the main policy-relevant conclusions.

The differences between Marshallian and

Hicksian elasticities are generally small but meaningful. For essential goods like cereals, Marshallian elasticities are slightly lower due to income effects reducing consumption, while for items with small budget shares, the differences are negligible. These results are consistent with theoretical predictions and evidence from developing countries (Falsafian *et al.*, 2024; Muiruri *et al.*, 2025).

In conclusion, the findings indicate that policy interventions should prioritize staple and high-consumption foods to ensure food security among low-income rural households. Price and expenditure elasticities suggest that targeted subsidies for cereals, proteins, and dairy products can effectively stabilize consumption of essential items. Additionally, the observed substitution and complementarity patterns among food groups provide actionable guidance for designing taxes, incentives, or educational campaigns to encourage healthier dietary choices. By explicitly linking elasticity estimates to policy instruments, our study demonstrates how demand analysis can inform evidence-based interventions in rural Iran.

Conclusion and Policy Implications

This study employed the QUAIDS model and the 2023 Household Income and Expenditure Survey (HIES) data to analyze rural food demand in Iran. The findings indicate that household consumption patterns are strongly influenced by income levels, relative prices, and demographic characteristics. Staple foods, such as cereals and proteins, are identified as necessities with low income and price elasticities, whereas vegetables and legumes exhibit more luxury-like behavior, with consumption rising at higher income levels. Cross-price elasticities reveal clear substitutive and complementary relationships among food groups, providing direct guidance for policy design. For example, modest taxes on sugary beverages can reduce consumption of both beverages and complementary sweets, while targeted support for staples like cereals, proteins, and dairy products can protect rural households from welfare losses due to price fluctuations.

Table 5– Uncompensated (Marshallian) price elasticities of food groups in rural Iran

Food group	Bread & cereals	Proteins	Dairy products	Oils & fats	Fruits & nuts	Vegetables & legumes	Sugar, sweets, and confectionery	Spices & beverages
Bread & Cereals	−0.873*	−0.249*	0.232*	0.967*	−0.205*	−0.366*	0.145**	−0.004
	(0.068)	(0.044)	(0.059)	(0.063)	(0.068)	(0.044)	(0.064)	(0.005)
Proteins	−0.452*	−0.608*	−0.128	−0.202***	0.150	−0.203*	0.262*	−0.005
	(0.070)	(0.080)	(0.086)	(0.113)	(0.098)	(0.066)	(0.100)	(0.007)
Dairy Products	0.093*	−0.035	−0.946*	0.127**	−0.111**	0.167*	−0.250*	−0.151*
	(0.029)	(0.027)	(0.060)	(0.054)	(0.053)	(0.032)	(0.052)	(0.042)
Oils & Fats	0.471*	−0.049	0.143**	−0.273**	−0.985*	−0.090**	−0.382*	−0.022
	(0.032)	(0.037)	(0.056)	(0.113)	(0.069)	(0.043)	(0.078)	(0.045)
Fruits & Nuts	−0.123*	0.076**	−0.116***	−1.123*	−0.077	0.144*	−0.094	0.057
	(0.038)	(0.036)	(0.062)	(0.079)	(0.096)	(0.046)	(0.073)	(0.051)
Vegetables & Legumes	−0.263*	−0.038	0.338*	−0.104	0.243*	−0.680*	−0.349*	−0.035
	(0.036)	(0.034)	(0.054)	(0.069)	(0.065)	(0.056)	(0.068)	(0.031)
Sugar, Sweets, and Confectionery	0.061**	0.098*	−0.241*	−0.372*	−0.082	−0.236*	−0.131	−0.193*
	(0.031)	(0.031)	(0.052)	(0.075)	(0.062)	(0.041)	(0.097)	(0.052)
Spices & Beverages	−0.004	−0.004	−0.151*	−0.024	0.054	−0.035	−0.189*	−0.207*
	(0.026)	(0.025)	(0.040)	(0.052)	(0.047)	(0.030)	(0.053)	(0.057)

Notes: Standard errors are reported in parentheses. Elasticities represent the responsiveness of household budget shares to changes in the prices of each food group. Asterisks denote the level of statistical significance (*: $p < 0.01$, **: $p < 0.05$, ***: $p < 0.10$).

Table 6– Compensated (Hicksian) price elasticities of food groups in rural Iran

Food group	Bread & cereals	Proteins	Dairy products	Oils & fats	Fruits & nuts	Vegetables & legumes	Sugar, sweets, and confectionery	Spices & beverages
Bread & Cereals	−0.857*	−0.282*	0.209*	0.967*	−0.203*	−0.314*	0.143**	−0.002
	(0.067)	(0.043)	(0.058)	(0.062)	(0.066)	(0.043)	(0.063)	(0.045)
Proteins	−0.428*	−0.658*	−0.163***	−0.200***	0.154***	−0.123***	0.259*	−0.018
	(0.066)	(0.078)	(0.083)	(0.111)	(0.095)	(0.063)	(0.097)	(0.087)
Dairy Products	0.100*	−0.051***	−0.957*	0.127**	−0.110**	0.192*	−0.251*	−0.160*
	(0.028)	(0.026)	(0.060)	(0.053)	(0.052)	(0.032)	(0.051)	(0.042)
Oils & Fats	0.479*	−0.065***	0.132**	−0.273**	−0.984*	−0.064	−0.383*	−0.022
	(0.031)	(0.036)	(0.055)	(0.113)	(0.069)	(0.042)	(0.077)	(0.054)
Fruits & Nuts	−0.114*	0.057***	−0.129**	−1.123*	−0.075	0.173*	−0.095	0.058
	(0.037)	(0.035)	(0.061)	(0.079)	(0.095)	(0.045)	(0.072)	(0.042)
Vegetables & Legumes	−0.250*	−0.065***	0.320*	−0.103	0.245*	−0.639*	−0.351*	−0.014
	(0.034)	(0.033)	(0.053)	(0.068)	(0.064)	(0.055)	(0.067)	(0.087)
Sugar, Sweets, and Confectionery	0.069**	0.082*	−0.252*	−0.372*	−0.081	−0.211*	−0.132	−0.194*
	(0.030)	(0.031)	(0.052)	(0.075)	(0.061)	(0.040)	(0.097)	(0.074)
Spices & Beverages	0.002	−0.017	−0.160*	−0.024	0.055	−0.015	−0.190*	−0.450*
	(0.025)	(0.024)	(0.039)	(0.052)	(0.046)	(0.029)	(0.053)	(0.034)

Notes: Standard errors are reported in parentheses. Elasticities represent the responsiveness of household budget shares to price changes, holding utility constant. Asterisks denote the level of statistical significance (*: $p < 0.01$, **: $p < 0.05$, ***: $p < 0.10$).

Demographic factors further contribute to heterogeneous consumption patterns. Household size and age influence dietary allocation, while higher educational attainment is associated with shifts toward healthier and more diversified diets. These results suggest that nutrition education programs can effectively complement fiscal and pricing measures to enhance food security in rural areas. Analysis of both uncompensated (Marshallian) and compensated (Hicksian) price elasticities shows that animal-based products are relatively price-sensitive, indicating that low-income households may face reductions in protein consumption without targeted interventions. In contrast, spices and beverages exhibit very low own-price elasticities, reflecting small budget shares and culturally ingrained consumption habits. These patterns underscore the importance of interpreting elasticity results within the context of local dietary practices.

Based on these findings, rural food policy in Iran should adopt a multidimensional approach that considers both the price sensitivity of different food groups and household heterogeneity. Broad subsidies are being phased out, so targeted mechanisms—such as conditional transfers, vouchers, or local price stabilization programs—can help vulnerable households access essential items during periods of price volatility. Support for price-elastic products like dairy and proteins can be implemented through temporary programs coordinated by local authorities. Nutrition education and outreach initiatives can improve diet quality, while promoting household-level food production can further enhance food security and complement fiscal measures. Policy interventions should also consider demographic characteristics, including household size, age, and education, to ensure that programs reach those most affected by dietary constraints.

While this study provides valuable insights into rural food demand and policy implications in Iran, it has some limitations. The analysis relies on cross-sectional HIES data, which may not fully capture temporal dynamics or seasonal variations in consumption and prices. Additionally, price data are based on aggregated regional averages, which could

mask local heterogeneity. Future research could address these limitations by employing time-series data, finer geographic disaggregation, or more detailed price and quantity measures to refine demand elasticity estimates and strengthen policy guidance.

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برآورد تقاضای مواد غذایی خانوارهای روستایی در ایران در چارچوب مدل QUAID: شواهدی برای طراحی سیاست‌ها

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چکیده

امنیت غذایی به‌عنوان یکی از مهم‌ترین ارکان توسعه پایدار و رفاه اجتماعی، به‌ویژه در جوامع روستایی، همواره تحت‌تأثیر تغییرات قیمتی و نوسانات درآمدی قرار دارد. در ایران، فشارهای تورمی سال‌های اخیر و کاهش قدرت خرید خانوارها، ضرورت تحلیل علمی الگوی تقاضای مواد غذایی و ارزیابی پیامدهای سیاست‌های حمایتی را بیش از پیش آشکار ساخته است. این پژوهش با هدف تحلیل سیاستی تقاضای مواد غذایی در مناطق روستایی ایران انجام شد. داده‌های مورد استفاده از پیمایش هزینه و درآمد خانوار سال ۱۴۰۲ استخراج گردید و برای برآورد الگوهای مصرفی، سیستم تقاضای QUAIDS با اعمال محدودیت‌های نظری و در نظر گرفتن متغیرهای جمعیت‌شناختی به‌کار گرفته شد. هشت گروه اصلی غذایی شامل غلات، پروتئین‌ها، لبنیات، روغن‌ها و چربی‌ها، میوه و خشکبار، سبزیجات و حبوبات، قند و شیرینی، و ادویه و نوشیدنی‌ها مورد بررسی قرار گرفتند. نتایج نشان داد که غلات و پروتئین‌ها در مناطق روستایی ایران ماهیت ضروری دارند و کشش‌های درآمدی و قیمتی آن‌ها پایین است، در حالی‌که گروه‌هایی مانند سبزیجات و حبوبات بیشتر به‌عنوان کالاهای لوکس عمل می‌کنند. بررسی کشش‌های قیمتی متقاطع بیانگر وجود روابط جانشینی و مکملی بین گروه‌های غذایی بود که در طراحی سیاست‌های قیمتی و مالیاتی اهمیت دارد. همچنین، متغیرهای جمعیت‌شناختی از جمله اندازه خانوار، تحصیلات و سن، تأثیر معناداری بر الگوی مصرف داشتند. یافته‌های پژوهش علاوه بر تأیید نتایج مطالعات مشابه داخلی و بین‌المللی، با ارائه شواهدی جدید در زمینه حساسیت تقاضای مواد غذایی به تغییرات درآمدی و قیمتی در ایران، بر ضرورت تدوین سیاست‌های چندبعدی در حوزه امنیت غذایی تأکید دارد. بر این اساس، بازنگری در یارانه‌های غذایی، طراحی حمایت‌های هدفمند برای کالاهای پرکشش، ارتقای آگاهی تغذیه‌ای، و توجه به ناهمگنی جمعیتی می‌تواند به بهبود رفاه و امنیت غذایی خانوارهای روستایی کشور کمک کند.

واژه‌های کلیدی: امنیت غذایی، تقاضای مواد غذایی، کشش قیمتی و درآمدی، مدل QUAIDS، مناطق روستایی

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