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Price and income elasticities of fruit demand in Poland: Evidence from Household Budget Data

1. Introduction

High fruit consumption plays a vital role in shaping public health, improving quality of life, and supporting socio-economic development. As a rich source of essential nutrients, fruits are crucial in the prevention of non-communicable diseases such as cardiovascular conditions, diabetes, and obesity. Research shows that increasing daily intake of fruits and vegetables to 800 grams significantly reduces the risk of cardiovascular diseases and reduces overall mortality (Aune et al. 2017). Similarly, Lee et al. (2019) emphasize the importance of fruit and vegetable consumption in reducing the risk of developing metabolic syndrome. Meanwhile, as indicated by Statistics Poland (GUS) data presented in Table 1, the average daily fruit consumption in Poland deviates substantially below the recommendations of the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), which advise a minimum daily intake of 400 grams of fruit per person (Caprile, Rossi 2021).

Low levels of fruit consumption in households stand in contrast to Poland's national production potential. According to data provided by Statistics Poland (GUS), annual fruit harvests in the country ranged between 4.92 million and 5.36 million tonnes between 2021 and 2023. According to Eurostat data (Eurostat 2022), in 2022 Poland held the second position among EU member states in fruit and nut production (excluding citrus), contributing 20.3% to the total EU output

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in this sector. Apple production dominates the domestic fruit sector, and Poland, being one of the world's largest producers and exporters of concentrated apple juice, effectively leverages its processing industry to manage production surpluses. According to the Ministry of Agriculture and Rural Development, the value of fruit and fruit product exports in the 2022/23 season reached €2.8 billion, representing a 9% increase compared to the previous season.

Table 1

Descriptive statistics of fruit consumption by socio-economic group and educational level (kg/person/month)

Household category	Mean	Median	Standard deviation
By socio-economic group			
Pensioners and retirees	5.21	4.14	4.35
Self-employed	4.06	3.17	3.58
Employees	3.86	3.00	3.40
Non-labor income sources	3.49	2.56	3.72
Farmers	3.43	2.60	3.53
By educational level of the household head			
Higher education	4.71	3.60	4.09
Secondary education	4.48	3.45	3.95
Below secondary education	3.99	3.03	3.57

Despite Poland's strong position as a fruit producer and exporter, the level of domestic fruit consumption does not reflect either the market's potential or public health expectations. An additional challenge is that a significant share of fruit consumption in Poland consists of imported fruits (such as citrus fruits and bananas), which not only limits opportunities to support the domestic market, but at the same time contributes to a higher carbon footprint and hampers the development of sustainable consumption practices.

Efforts to increase fruit consumption in Poland, as well as to shift its structure, above all require a better understanding of the economic mechanisms that influence consumer decision-making. In this context, the analysis of complete demand models can be particularly helpful, as they make it possible to determine how changes in the prices of individual products and in consumers' income levels related to demand for various types of fruit. This, in turn, allows for the estimation

of which products are more sensitive to price or income changes, and therefore which interventions (e.g., price reductions, subsidies, informational campaigns) are likely to be most effective in improving consumption levels (Wolak 2015).

Contemporary empirical studies also reveal significant relationships between fruit consumption and socio-economic factors such as household structure, age, or health-related needs (Mauramo et al. 2023). Understanding these relationships is important not only from a public health perspective, but also for designing effective policies that support the agricultural sector, prevent food waste, and promote responsible consumption

Although numerous applications of complete demand models for analysing fruit consumption can be found in the global literature (e.g., Peltner, Thiele 2021; Iqbal et al. 2023), there is still a notable absence of advanced demand analyses based on complete demand system estimations for the Polish fruit market – despite its significant economic and dietary relevance. This study seeks to fill this clear research gap.

The analysis is based on unit-level data from the 2022 Household Budget Survey conducted by Statistics Poland. Six fruit categories were considered: citrus fruits, bananas, apples, berries, stone fruits, and other fruits. To estimate income and price elasticities of demand, the QUAIDS model (Quadratic Almost Ideal Demand System) was employed, accounting for zero expenditures and the influence of selected demographic variables. The results indicate that fruit demand is sensitive to changes in both prices and income, particularly in the case of imported fruit.

The rest of the article is structured into following sections. Section 2 presents a literature review focused on methods of analysing fruit demand and the econometric models, including the QUAIDS model. Section 3 discusses the study's methodology, covering data sources, the procedure for determining unit prices, and the specifics of the applied model, including the calculation of price and income elasticities. Section 4 outlines the results of the model estimation, including an analysis of the obtained elasticity values and their potential implications. The article concludes with a summary of the main findings and recommendations for future research and the practical application of the results.

2. Literature review

The academic literature pays considerable attention to both the theoretical foundations of consumption modelling and empirical analyses of demand for various categories of food products. In addition to studies covering a spectrum of food

items (e.g., Mjeda et al. 2020; Korir et al. 2020), particular interest has been given to those product groups whose consumption can be relatively easily influenced by government policies, primarily through fiscal instruments such as indirect taxation. Many examples include numerous analyses concerning alcohol (e.g., Gil, Molina 2009; Aepli 2014) and sugar-sweetened beverages (e.g., Caro et al. 2017; Segovia et al. 2020; Wolak 2021), the consumption of which is often subject to regulation due to its adverse health effects.

In this context, it appears justified to extend the analytical perspective to include products whose consumption may bring potential health benefits. A good example is fruit. In this case, government action aims not so much to limit consumption as to support it, both by promoting healthy eating habits and by strengthening the position of domestic producers.

The literature includes studies that examine fruit demand using a demand system approach. Mekonnen et al. (2012), using annual data from 1980 to 2007 on per capita fruit consumption in the United States, estimated a QUAIDS model that incorporated three product groups: fresh fruit, fruit juices, and processed fruit. Their findings indicate that demand for all the categories considered was price inelastic, and the relationships between them were complementary. This result is particularly relevant in the context of designing policies to promote fruit consumption, as it shows that increased demand for one form of fruit encourages consumption of the others. Demand analyses based on household budget expenditure data have also been conducted for selected developing countries, for example Malaysia (Ashagidigbi et al. 2019) and Pakistan (Iqbal et al. 2023). The authors of these studies, using different specifications of the AIDS (Deaton, Muellbauer 1980) or QUAIDS (Banks et al. 1997) models, came to fairly similar conclusions. Fruits were found to be normal goods with price-inelastic demand, and various demographic factors (including place of residence, household size, as well as the age or gender of the household head) were shown to significantly influence consumption levels.

In the Polish literature, there is a noticeable lack of studies devoted to the demand for distinct categories of fruit. Most of them focus on general analyses of food demand, in which fruit constitutes only one of many product categories considered (e.g., Gulbicka, Kwasek 2006; Kwasek 2008; Stanisławska, Wysocki 2011), or is limited to estimating income elasticities using nonlinear demand models (Dorosz, Dudek 2020). Previous approaches rarely incorporate the a priori conditions derived from microeconomic theory, which limits the ability to comprehensively capture the structure of fruit consumption.

In response to these limitations, the present study proposes the application of a complete demand system model that enables a more detailed analysis of

the interrelationships among selected product categories. Although such models have been employed in Polish research, for example, in the analysis of household consumption expenditure structures (Gostkowski 2018) or specific product groups such as alcohol (Gurgul, Wolak 2008), staple food products (Dudek 2008), or sugar-sweetened beverages (Wolak 2021), they have not yet been applied to the study of fruit demand. As a result, this area remains underexplored in the Polish context.

3. Methods

This chapter presents the methodological framework adopted in the study. It begins with a description of the data source and construction of the price variables used in the analysis. Subsequently, demographic controls and their integration into the demand model are discussed. The core of the methodology involves the specification of a QUAIDS model adapted to handle zero expenditures, estimated in two stages. Finally, formulas for computing demand elasticities are outlined based on the estimated model coefficients.

3.1. Data set

The empirical part of this study is based on anonymized unit-level data obtained from the Household Budget Survey conducted by Statistics Poland (GUS) in 2022. This survey is carried out annually using a representative sampling method. In 2022, the sample covered 28,383 households, described by a wide range of demographic and socio-economic characteristics. Each participating household recorded, for a selected month, information on income received as well as the quantities purchased and total expenditures on selected categories of goods. This study used data on the quantities purchased in the following six fruit categories:

- citrus fruits (e.g., oranges, pomelo, grapefruit, lemons, mandarins),
- bananas,
- apples,
- berries (e.g., gooseberries, chokeberries, blueberries, bilberries, blackberries, raspberries, currants),
- stone fruits (e.g., peaches, apricots, nectarines, sweet cherries),
- other fruits (e.g., grapes, watermelons, melons, pomegranates).

Monthly household-level consumption data by fruit category are presented in Table 2.

Table 2

Descriptive statistics of unit prices by fruit category (PLN per kg)

Fruit category	Mean	Median	Standard deviation
Citrus fruits	1.92	0.99	2.77
Bananas	1.79	1.18	2.05
Apples	2.38	1.45	3.29
Berries	1.14	0.30	2.32
Stone fruits	0.85	0.00	2.16
Other fruits	1.14	0.00	2.33

3.2. Unit prices

There is an ongoing debate in the literature regarding the validity of using unit prices, defined as the ratio of expenditures to quantities purchased, as a proxy for market prices. While A. Deaton recognized the potential of unit values to approximate actual market prices, he also pointed out the limitations of this approach due to quality effects and demographic differences among households (Deaton 1988). A major methodological contribution was made by T.L. Cox and M.K. Wohlgenant, who suggested adjusting for product quality by regressing unit prices on selected household characteristics (Cox, Wohlgenant 1986). Their approach has since been extended in various contexts.

Deaton's framework (Deaton 1988, 1990) for analysing demand using household-level data relies on the assumption of price constancy within local markets. While this assumption simplifies empirical implementation, it may not accurately reflect price variation actually faced by households, particularly in regions with imperfect market integration or limited data granularity. Recognizing this limitation, L.V. Hoang proposed an alternative approach by incorporating regional average prices to better capture the effective prices consumers are exposed to (Hoang 2009). This modification allows for more accurate estimation of demand parameters by accounting for intra-regional price dispersion, and has since informed subsequent studies aiming to improve the robustness of demand system estimation using survey data. Nowadays, such adjusted approaches, tailored to the specific structure of the data, are widely adopted in demand analyses (Majumder et al. 2012; Aepli 2014; Wolak 2021).

The present study follows this line of methodology. It is assumed that quality effects are influenced by household income and selected demographic

characteristics (i.e., household size, income and squared income, number of children, and the educational level of the household head). These effects are modelled as the deviation between the unit price paid by a household and the regional average unit price, accounting for temporal variation. To estimate adjusted market prices, the following regression equation is proposed

$$v_i - \left(v_i\right)_{median} = \alpha_i D_l + \gamma_i D_q + \delta_i x + \theta_i x^2 + \sum_{j=1}^{n} b_i Z_{ij} + \varepsilon_i \quad (1)$$

where:

v_i – denote the unit value (unit price) paid by a household for product i in quarter q and region l,
D_l – be a categorical variable for region,
D_q – be a categorical variable for quarter,
x – represents household income,
Z_{ij} – be a set of demographic characteristics of household j.

The estimation of Equation (1) was performed separately for each of the six fruit categories using a robust M-estimator, which reduces the influence of outliers (Aepli, Finger 2013). Quality-adjusted prices, accounting for regional and temporal differences, were computed using the following formula

$$\left(p_i\right)_{med} = \left(v_i\right)_{med} + \left(\varepsilon_i\right)_{med} \quad (2)$$

where:

$(v_i)_{med}$ – is the median unit value paid by households for product i in quarter q and region l,
$(\varepsilon_i)_{med}$ – is the median of the residuals from Equation (1) for households that purchased product i in the same quarter and region.

3.3. Demographic variables

The literature identifies two main approaches for incorporating demographic variables into the QUAIDS model equations. The scaling approach, proposed by R. Ray, involves adjusting household income through a demographic scaling function (Ray 1983). This allows the model to account for differences in household composition and size.

The translating approach (Pollak, Wales 1981), which can be expressed by Equation (3).

$$\alpha_i = \alpha_i' + \sum_{k=1}^{K} \eta_{ik} Z_k \quad (3)$$

The household characteristics Z_k are introduced into the model by modifying the constant term α_i. Although the translating approach is more restrictive than the scaling approach, it enables direct modelling of the impact of household characteristics on consumption structure. Moreover, it is better suited to data with zero expenditures and allows for theoretically consistent estimation of the model (Caro et al. 2021).

3.4. QUAIDS model with zero-expenditures

Failure to account for zero expenditures in demand analysis can lead to biased estimates. For this reason, the literature proposes several techniques to address this issue. D. Heien and C.R. Wessells introduced a two-step procedure in which a probit model is first estimated to determine the probability of purchasing a given good (Heien, Wessells 1990). In the second step, an inverse Mills ratio is added to the demand model, and the parameters are estimated accordingly.

J.S. Shonkwiler and S.T. Yen proposed a refinement of this approach, offering a more consistent and less error-prone two-step estimation method (Shonkwiler, Yen 1999). In their procedure, probit models are estimated in the first stage to predict the probability of purchasing each product. If y_{ij} denotes the expenditure of household j on good i, new variables are generated according to Equation (4).

$$y_{ij}^{*} = \begin{cases} 1 & if \;\; y_{ij} > 0 \\ 0 & if \;\; y_{ij} = 0 \end{cases} \tag{4}$$

The newly constructed binary variables are then used to build probit models that explain the probability of expenditure on good i based on selected household characteristics.

$$y_i^{*} = \sum_{k=1}^{K} \theta_{ik} Z_{ik} + \varepsilon_i \tag{5}$$

In the second stage, using the results of the probit regressions (4), values of the probability density function ϕ_i and the cumulative distribution function Φ_i are computed. These are then incorporated into the demand system equations to adjust for the presence of zero expenditures. For QUAIDS, the equation for the i-th good in the system takes the following form

$$w_i^{*} = \Phi_i M_i + \delta_i \phi_i + u_i \tag{6}$$

where M_i represents the i-th equation of the original QUAIDS model, in which demographic variables are incorporated using the translating approach.

$$\alpha_i + \sum_{i=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{m}{a(\mathbf{p})}\right) + \frac{\lambda_i}{b(\mathbf{p})}\left[\ln\left(\frac{m}{a(\mathbf{p})}\right)\right]^2 + \sum_{k=1}^{K} \eta_{ik} Z_k \tag{7}$$

In Equations (5)–(7), ln p_j denotes the logarithm of prices within the corresponding category of fruit, m represents total household expenditure on fruit, and Z_k refers to the demographic variables under consideration $a(p)$ and $b(p)$ are price indices. The symbol Φ_i denotes the cumulative distribution function value from the probit model, while ϕ_i refers to the value of the probability density function. The parameters α_i, γ_{ik}, β_i, η_{ik} and δ_i are estimated model coefficients, and u_i represents the error term.

3.5. Demand elasticities in the QUAIDS model

One of the main objectives of estimating demand system parameters is to derive income and price elasticity values based on the estimated coefficients. In the censored version of the QUAIDS model, elasticity measures are computed using formulas derived from the estimated model parameters (Caro et al. 2021). The income elasticity of demand is defined by the following identity (8).

$$\eta_i = 1 + \frac{1}{w_i^*}\left\{\Phi_i\left(\beta_i + \frac{2\lambda_i}{b(\mathbf{p})}\ln\left(\frac{m}{a(\mathbf{p})}\right)\right) + \theta_{i,\ln(m)}\phi_i\left[w_i - \delta_i y_i^*\right]\right\} \tag{8}$$

The uncompensated (Marshallian) price elasticity of demand is calculated using the following formula

$$\varepsilon_{ij}^M = -\delta_{ij} + \frac{1}{w_i^*}\left\{\Phi_i\left[E_{ij}\right] + \theta_{i,\ln(p_j)}\phi_i\left[w_i - \delta_i y_i^*\right]\right\} \tag{9}$$

$$\eta_i = 1 + \frac{1}{w_i^*}\left\{\Phi_i\left(\beta_i + \frac{2\lambda_i}{b(\mathbf{p})}\ln\left(\frac{m}{a(\mathbf{p})}\right)\right) + \theta_{i,\ln(m)}\phi_i\left[w_i - \delta_i y_i^*\right]\right\} \tag{10}$$

where δ_{ij} is the Kronecker delta, taking the value of 1 when $i = j$ and 0 otherwise.

Estimates of the compensated (Hicksian) price elasticity of demand are obtained by applying the Slutsky equation (Banks et al. 1997).

$$\varepsilon_{ij}^H = \varepsilon_{ij}^M + \eta_i w_j \tag{11}$$

4. Results and discussion

In the first stage of the empirical analysis, in accordance with the approach described in Section 3.1 and based on Equation (1), unit prices for individual fruit categories were estimated, adjusted for quality and differentiated by region and quarter. To ensure price consistency within local markets, households were grouped according to voivodeship, type of settlement, and rural area delimitation. The calculations also accounted for selected demographic variables, such as household size, the number of children under the age of 18, and the educational level of the household head. The estimated unit prices are presented in Table 3.

Table 3

Descriptive statistics of unit prices by fruit category

Fruit category	Mean	Median	Standard deviation
Citrus fruits	7.09	7.26	1.10
Bananas	5.70	5.77	0.55
Apples	2.92	2.98	0.33
Berries	12.73	12.74	3.17
Stone fruits	11.33	11.74	3.87
Other fruits	5.95	6.29	1.28

Next, using the price data presented in Table 3 along with information on the quantity of consumption for each fruit category, budget shares were calculated for all six defined categories. These are presented in Table 4. As can be observed, the largest portion of the fruit-related household budget in Poland is allocated to imported goods (citrus fruits and bananas) followed by domestically harvested fruits such as berries and apples.

Table 4

Descriptive statistics of budget shares by fruit category

Fruit category	Mean	Median	Standard deviation
Citrus fruits	0.24	0.17	0.25
Bananas	0.21	0.16	0.22

Table 4 cont.

Apples	0.16	0.09	0.20
Berries	0.19	0.09	0.24
Stone fruits	0.11	0.00	0.18
Other fruits	0.10	0.00	0.15

The analysed data show the presence of so-called zero expenditures, meaning that during the reference period some households did not report any purchases in specific fruit categories. Depending on the type of fruit, the proportion of zero expenditures ranged from 23.5% for citrus fruits to as high as 60.0% for stone fruits.

As a result, in the next stage of the analysis, a QUAIDS model adapted to handle zero expenditures was estimated. In the first step, following Equation (5), probit models were estimated. This was followed by the estimation of the system of equations – Equation (7), with parameter restrictions imposed to ensure that the conditions of adding-up, homogeneity, and symmetry of substitution effects were satisfied.

The model also included a demographic variable representing the number of household members being fed. Estimation was carried out using a nonlinear least squares method, following the approach presented by Caro et al. (2021). Finally, based on Equations (8– 10), uncompensated price and income elasticities of demand were computed for each fruit category. The results are presented in Table 5 and 6.

Table 5

Uncompensated price elasticities of fruit demand

	Citrus fruits	Bananas	Apples	Berries	Stone fruits	Other fruits
Citrus fruits	−3.07	0.87	−0.43	0.25	0.11	0.48
Bananas	0.41	−1.58	1.30	−0.66	2.55	2.44
Apples	−0.30	−0.07	−1.02	0.15	0.27	0.13
Berries	2.17	−0.95	0.69	−0.63	0.01	0.00
Stone fruits	4.27	−1.96	1.77	0.72	−1.62	−2.38
Other fruits	0.43	−0.52	0.19	0.09	−0.09	−0.95

Table 6

Income elasticities of fruit demand

Fruit category	Demand elasticities
Citrus fruits	1.09
Bananas	2.36
Apples	0.73
Berries	1.76
Stone fruits	1.94
Other fruits	1.37

The own-price Marshallian elasticities of demand, presented in Table 5, indicate that an increase in the price of each fruit category leads to a decline in demand. In three out of six cases, the decrease in demand is more than proportional to the price change, with elasticity values for citrus fruits (−3.07), bananas (−1.58), and stone fruits (−1.62). Demand for apples (−1.02) and other fruits (−0.95) is approximately unit elastic, while berries (−0.63) are the only category exhibiting inelastic demand.

The estimated income elasticities indicate that all considered fruit categories can be classified as normal goods. Apples show the lowest income elasticity (0.73), whereas other categories – including bananas (2.36), which appear most sensitive to changes in household income – demonstrate a more than proportional response of demand to income variation.

These findings may serve as a foundation for developing a comprehensive strategy aimed at increasing fruit consumption in Poland. Given the relatively high estimates of price elasticity, well-designed price incentives could be an effective tool of public policy. In particular, the government, drawing on the provisions of the revised EU VAT Directive, could follow the example of Ireland and consider reducing the VAT rate on fresh fruit to 0%. Such a policy, if fully reflected in retail prices, could significantly stimulate demand across all analysed fruit categories.

At the same time, due to the relatively high income elasticities, it would be advisable to consider expanding the "Fruit and Vegetables at School" programme to include students in upper primary and secondary schools. Such an intervention could not only support local producers but also promote healthy eating habits among adolescents and, in the longer term, contribute to an overall increase in fruit consumption in Poland.

5. Conclusion

The aim of this study was to analyse household demand patterns for selected fruit categories in Poland, with particular focus on their sensitivity to changes

in prices and income. To estimate income and price elasticities of demand for six fruit categories (citrus fruits, bananas, apples, berries, stone fruits, and other fruits), the QUAIDS model was employed, using data from the 2022 Household Budget Survey conducted by Statistics Poland.

The findings from this analysis may serve as a basis for designing effective strategies and promotional campaigns aimed at increasing fruit consumption. Due to the limited number of studies focusing on the Polish market, a broader comparison of results with previous years or analogous studies could not be performed. In the future, it would be particularly valuable to investigate fruit demand across income groups or to focus on specific demographic segments.

At the same time, several limitations of this study should be acknowledged. First, fruit consumption is known to exhibit strong seasonal variation. Incorporating calendar effects, such as holidays or harvest periods, into future models could enhance the precision of estimates. Second, the use of scanner data, such as retail transaction records, could provide more accurate and timely insights into consumer responses to price changes and promotional campaigns. Incorporating these elements in future research would significantly strengthen the empirical foundation of demand analyses and align them more closely with contemporary approaches in consumer microeconomics.

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Summary

The aim of this article is to provide an empirical analysis of fruit demand in Polish households using the QUAIDS model. Based on unit-level data from the 2022 Household Budget Survey conducted by Statistics Poland (GUS), income and price elasticities were estimated for six fruit categories: citrus fruits, bananas, apples, berries, stone fruits, and other fruits. The estimation employed the two-step procedure developed by J.S. Shonkwiler and S.T. Yen, accounting for demographic variables and the issue of zero expenditures. The results indicate high sensitivity of fruit demand to changes in both prices and income, particularly for imported fruits. The article provides recommendations for public policy aimed at supporting the domestic fruit market and promoting healthy dietary habits.

JEL codes: D12, Q18, I18

Keywords: *fruit demand, QUAIDS model, demand elasticities, household consumption*