The estimation of the Marshallian demand functions for the selected foodstuff groups according to the households income quartils

Odhad Marshallovych dopytových funkcií vybraných skupín potravín podľa príjmových kvartilov domácností

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Abstract: The article deals with the modelling of demand for the food group of milk and milk products and the food group of meat, meat products, eggs and fish using the Marshallian demand functions for the individual income quartils of Slovak households. The criterium for the foodstuff groups selection is their position in the Healthy Eating Pyramid which is one of the recommended optimal food basket forms. We suppose that the significant income differentiation of households will manifest as different consumer behaviour in the food market. The analysis confirms this hypothesis.

Key words: consumption of foodstuffs, income quartil, Marshallian demand function, demand elasticity of foodstuffs, foodstuff group of milk and milk products, foodstuff group of meat, meat products, eggs and fish

Abstrakt: Cieľom príspevku je kvantifikovať vplyv zmeny ceny a príjmu na spotrebu vybraných skupín potravín. Do analýzy sú zahrnuté dve potravinové skupiny. Prvá skupina je tvorená mliekom a mliečnymi výrobkami, druhá skupina mäsom, mäsovými výrobkami, vajcami a rybami. Kritériom výberu potravinových skupín bol ich podiel na celkovej spotrebe potravín odporúčaný výživovou pyramídou, ktorá je jednou z foriem odporúčaného optimálneho potravinového koša. Skupina mlieko a mliečne výrobky a skupina mäso, mäsové výrobky, vajcia a ryby majú rovnaký odporúčaný podiel na celkovej spotrebe potravín. Predpokladali sme, že výrazná príjmová diferenciácia domácností sa prejaví v rozdielnom správaní sa spotrebiteľov na trhu s potravinami. Analýza túto hypotézu potvrdila.

Kľúčové slová: spotreba potravín, kvartil príjmu, Marshallova dopytová funkcia, elasticita dopytu po potravinách, potravinová skupina mlieko a mliečne výrobky, potravinová skupina mäso, mäsové výrobky, vajcia a ryby

Food policy is a part of the nutrition policy of the Slovak government. The aim of these policies as well as the aim of the agricultural policy (Bielik et at. 2007) is to provide the sufficiency of the appropriate and healthy foodstuffs. From this point of view, the identification of the factors affecting the demand for foodstuffs is very helpful. The rules of rational nutrition are often presented through the Healthy Eating Pyramid.

MATERIAL AND METHODS

Consumers' behaviour in the food market can be differentiated due to the significant income differentiation. The aim of this paper is to identify the effect of price and money income in Slovak households on the selected food groups consumption.

For the analysis requirements, the consumers are divided into four income groups – quartils, based on the level of the average annual income. These income quartils are provided by the database of the Statistical Office of the SR. The lowest income group of households forms the 1st quartil, the highest income group of households forms the 4th quartile.

The article deals with the modelling of demand for the food group of milk and milk products and the food group of meat, meat products, eggs and fish. The criterion for the foodstuffs groups selection is their position in the Healthy Eating Pyramid which is

one of the recommended optimal food basket forms. Both these foodstuffs groups are situated just under the top of the pyramid (the top of the pyramid – fats and sweets, the least recommended foodstuffs group; the basis of pyramid – wholegrain products, the most recommended foodstuffs group) and their recommended share is 12.5% in the total food consumption (Zentková, Hošková 2008).

The nominal values of the monetary variables included into the analysis such as money income and prices of foodstuffs are transformed into the real values using the base consumer price index (Ševela 2004). In respect of the fact that the Statistical Office of the SR did not monitor the foodstuffs consumption according to the income quartiles before the year 2000, there are used the eight-year long time series which include the period of years 2000–2007.

The impact of the change in households' real money income and the change in the average real prices of the selected foodstuffs groups on the consumption of these groups of foodstuffs is quantified by the means of the Marshallian demand functions (Varian 1992) and the demand elasticities estimation.

The general Marshallian demand function of *k*-th foodstuff group for *j*-th income quartile is:

$$q_{kj} = d_{kj}\,(ri_{j,}\, rp_k)\; k = 1.2 \quad j = \overline{1.4} \qquad (1)$$

where:

q_{kj} – quantity demanded for *k*-th foodstuff group in *j*-th income quartile in kg

$d_{kj}\,(rp_k, ri_j)$ – demand function for *k*-th foodstuff group in *j*-th income quartile

ri_j – net annual real income in SKK per capita in *j*-th income quartile

rp_k – average real price of *k*-th foodstuff group in SKK (computed as a weighted price average of *k*-th foodstuffs group, where weight is the share of individual foodstuffs consumption on the total consumption of *k*-th foodstuffs group)

For the modelling of the empirical Marshallian demand functions, there are used the linear, exponential and power regression models (Zentková, Hošková 2006). The requirement of economic sense of the estimate regression parameters is, besides others, important for the model selection process.

The linear empirical Marshallian demand equation of *k*-th foodstuffs group for *j*-th income quartile is:

$$q_{kj} = a + b_1 \times ri_j + b_2 \times rp_k \qquad (2)$$

where:

a – intercept

b_1, b_2 – regression coefficients

$q_{kj}, ri_{j,}\, rp_k$ – ditto (1)

Income demand elasticity of *k*-th foodstuffs group in *j*-th income quartile derived from the linear Marshallian demand equation is calculated as follows:

$$E_{IDkj} = \Delta r_{ij} \xrightarrow{\lim} 0 \begin{bmatrix} d_{kj}(ri_j + \Delta ri_j, \overline{rp_k}) - \\ - d_{kj}(ri_j, \overline{rp_k}) \end{bmatrix} /$$

$$/\,\Delta ri_j \times \frac{ri_j}{q_{kj}} = \frac{\partial q_{kj}}{\partial ri_j} \times \frac{ri_j}{q_{kj}} = b_1 \times \frac{ri_j}{q_{kj}} \qquad (3)$$

where:

E_{IDkj} – income demand elasticity of *k*-th foodstuffs group in *j*-th income quartile

b_1 – ditto (2)

$$ri_j = \frac{\sum_{i=1}^{n} ri_{ij}}{n} \qquad q_{kj} = \frac{\sum_{i=1}^{n} q_{ikj}}{n} \qquad n = 8$$

where:

ri_{ij} – net annual real income per capita in SKK in *j*-th income quartile in *i*–th year

q_{ikj} – consumption of *k*-th foodstuffs group in kg in *j*-th income quartile in *i*-th year

Price demand elasticity of *k*-th foodstuffs group in *j*-th income quartile derived from the linear Marshallian demand equation is calculated as follows:

$$E_{PDkj} = \Delta rp_k \xrightarrow{\lim} 0 \begin{bmatrix} d_{kj}(\overline{ri_{kj}}, rp_k + \Delta rp_k) - \\ - d_{kj}(\overline{ri_{kj}}, rp_k) \end{bmatrix} /$$

$$/\,\Delta rp_k \times \frac{rp_k}{q_{kj}} = \frac{\partial q_{kj}}{\partial rp_k} \times \frac{rp_k}{q_{kj}} = b_2 \times \frac{rp_k}{q_{kj}} \qquad (4)$$

where:

E_{PDkj} – price demand elasticity of *k*-th foodstuffs group in *j*-th income quartile

b_2 – ditto (2)

$$rp_k = \frac{\sum_{i=1}^{n} rp_{ik}}{n};\; n = 8$$

where:

q_{ki} – ditto (3)

rp_{ik} – real price of *k*-th foodstuffs group in SKK in *i*-th year

The power empirical Marshallian demand equation of *k*-th foodstuffs group for *j*-th income quartile is:

$$q_{kj} = a \times ri_j^{b1} \times rp_k^{b2} \qquad (5)$$

The linear logarithmic transformation is:

$$\ln q_{kj} = \ln a + b_1 \times \ln ri_j + b_2 \times \ln rp_k \quad (6)$$

where:
q_{kj}, ri_j, rp_k – ditto (1)
a, b_1, b_2 – ditto (2)

The income demand elasticity of k-th foodstuffs group in j-th income quartile derived from the power Marshallian demand equation is calculated as follows:

$$E_{IDkj} = \frac{\partial q_{kj}}{\partial ri_j} \times \frac{ri_j}{q_{kj}} = \frac{b_1 \times a \times ri_j^{b_1} \times rp_k^{b_2}}{ri_j} \times$$

$$\times \frac{ri_j}{a \times ri_j^{b_1} \times rp_k^{b_2}} = b_1 \quad (7)$$

resp. $$E_{IDkj} = \frac{\partial \ln q_{kj}}{\partial \ln ri_j} = b_1 \quad (8)$$

where:
E_{IDkj} – ditto (3)
b_1 – ditto (2)

Price demand elasticity of k-th foodstuffs group in j-th income quartile derived from the power Marshallian demand equation is calculated as follows:

$$E_{PDkj} = \frac{\partial q_{kj}}{\partial rp_k} \times \frac{rp_k}{q_{kj}} = \frac{b_2 \times a \times ri_j^{b_1} \times rp_k^{b_2}}{rp_k} \times$$

$$\times \frac{rp_k}{a \times ri_j^{b_1} \times rp_k^{b_2}} = b_2 \quad (9)$$

$$E_{PDkj} = \frac{\partial \ln q_{kj}}{\partial \ln rp_k} = b_2 \quad (10)$$

where:
E_{PDkj} – ditto (4)
b_2 – ditto (2)

Exponential empirical Marshallian demand equation of k-th foodstuffs group for j-th income quartile is:

$$q_{kj} = a \times b_1^{rij} \times b_2^{rpk} \quad (11)$$

Linear logarithmic transformation is:

$$\ln q_{kj} = \ln a + \ln b_1 \times ri_j + \ln b_2 \times rp_k \quad (12)$$

q_{kj}, ri_j, rp_k – ditto (1)
a, b_1, b_2 – ditto (2)

Income demand elasticity of k-th foodstuff group in j-th income quartile derived from the exponential Marshallian demand equation is calculated as follows:

$$E_{IDkj} = \frac{\partial q_{kj}}{\partial ri_j} \times \frac{ri_j}{q_{kj}} = (a \times b_1^{ri_j} \times \ln b_1 \times b_2^{rp_k}) \times$$

$$\times \frac{ri_j}{a \times b_1^{ri_j} \times b_2^{rp_k}} = \ln b_1 \times ri_j \quad (13)$$

resp. $$E_{IDkj} = \frac{\partial \ln q_{kj}}{\partial ri_j} \times ri_j = \ln b_1 \times ri_j \quad (14)$$

where:
E_{IDkj}, ri_j – ditto (3)
b_1 – ditto (2)

Price demand elasticity of k-th foodstuffs group in j-th income quartile derived from the exponential Marshallian demand equation is calculated as follows:

$$E_{PDkj} = \frac{\partial q_{kj}}{\partial rp_k} \times \frac{rp_k}{q_{kj}} = (a \times b_1^{ri_j} \times b_2^{rp_k} \ln b_2) \times$$

$$\times \frac{rp_k}{a \times b_1^{ri_j} \times b_2^{rp_k}} = \ln b_2 \times rp_k \quad (15)$$

resp. $$E_{PDkj} = \frac{\partial \ln q_{kj}}{\partial rp_k} \times rp_k = \ln b_2 \times rp_k \quad (16)$$

where:
E_{PDk}, rp_{kj} – ditto (4)
b_2 – ditto (2)

For the overall explanatory power of the entire regression models of the Marshallian demand function, there are used the test of goodness of fit and correlation (adjusted R-squared, coefficient of determination) and F-statistics. t-statistic is used for testing the hypothesis that the parameters are statistically significant. Because the regression analysis may face some serious problems, there are use the tests available to detect the presence of multicolinearity (Farrar-Glauber test), heteroscedasticity (White test) and autocorrelation (Durbin-Watson test) (Greene 1993).

RESULTS AND DISCUSSION

Consumers' foodstuffs purchase decision making is determined by many factors. The price of foodstuffs

and the consumers' money income are generally considered as the most significant determinants (Varian 1992). The demand for foodstuffs is also effected by such factors as the price of foodstuffs substitutes, life style, alimentation habits, willingness to accept the rational nutrition recommendations and many other factors quantified with difficulties (Syrovátka 2004).

Income differentiation and food consumption

The basic characteristics of the individual quartiles of the households' income groups are provided in the Table 1.

Compared to the lowest income group (1st quartile), the consumers in the 4th quartile earn almost 3-times higher income and the growth rate of their nominal money income is by one third higher. The data showed in Table 1 confirm the Engel's law that the welfare increase (measured by the level of real income) leads to decreasing of the share of food expenditures in the total consumers expenditures. This tendency can be seen the world-wide (Zentková, Hošková 2006). The share of food expenditures in the 1st quartile is 30%, in the 4th quartile only 18%.

Table 2 shows the share of milk and milk products consumption and meat, meat products, eggs and fish consumption in the total foodstuffs consumption of Slovak consumers split up into the income quartiles. The shares of the consumption of both analysed foodstuffs groups in the total foodstuffs consumption differ significantly from the recommended share 12.5% in all income quartiles.

The share of milk and milk products foodstuffs group in the total foodstuffs consumption is in average 14.3% over the share recommended by the Healthy Eating Pyramid. The share of the mentioned foodstuffs group consumption slightly declines when the income increases (negative correlation between money income and consumption). During the analysed years 2000–2007, the share of milk and milk products in the total foodstuffs consumption went down in average by about 13%.

The meat, meat products, eggs and fish consumption of the Slovak consumers approaches the recommendations of the Healthy Eating Pyramid a little bit more.

Table 1. Incomes and expenditures according to the income quartiles

Indicator	1st quartile		2nd quartile		3rd quartile		4th quartile	
	SKK	07/00	SKK	07/00	SKK	07/00	SKK	07/00
Net nominal income*	52 203	1.99	75 257	2.11	93 866	2.11	146 990	2.28
Net real income*	47 247	1.81	68 015	1.92	84 848	1.92	132 688	2.07
Nominal foodstuffs expenditures*	14 645	1.35	18 285	1.34	21 200	1.31	22 460	1.30
Real foodstuffs expenditures*	13 257	1.23	16 576	1.22	19 207	1.19	20 416	1.19
Share of foodstuffs expenditures**	29	0.89	27	0.90	25	0.91	18	0.85

*SKK per capita and year, **in total households' expenditures in %

Source: Statistical Office of the SR, authors' calculations

Table 2. Share of the individual foodstuffs groups consumption in the total foodstuffs consumption in SR in %

Foodstuffs group	1st quartile			2nd quartile		
	2000	2007	mean 2000–2007	2000	2007	mean 2000–2007
Milk and milk products	35.1	21.3	28.2	37.5	20.9	27.5
Meat, meat products, eggs, fish	11.1	16.1	13.5	11.9	17.1	14.7
Foodstuffs group	3rd quartile			4th quartile		
	2000	2007	mean 2000–2007	2000	2007	mean 2000–2007
Milk and milk products	34.0	20.0	27.1	31.5	19.9	24.9
Meat, meat products, eggs, fish	12.9	17.2	15.0	14.3	17.6	16.1

Source: Statistical Office of the SR, authors' calculations

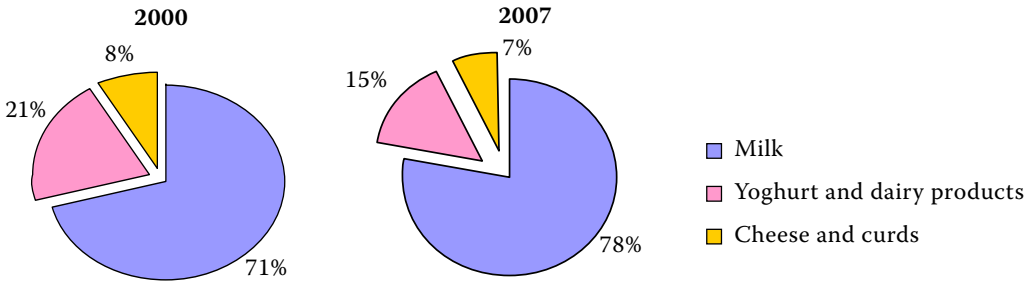

Figure 1. The comparison of milk and milk products consumption structures in the years 2000 and 2007

Source: Statistical Office of the SR, authors' calculations

The difference between the real and recommended shares is in average only 2.3%. In difference to milk and milk products foodstuffs group, there appears a positive correlation between the money income and consumption. When the income increases, the share of meat, meat products, eggs and fish consumption raises, too.

Modelling of demand for milk and milk products

Figure 1 shows the comparison of milk and milk products consumption structures in the years 2000 and 2007. The share of cheese and curds consumption is too low in both years and did not change significantly. From the nutrition recommendation point of view, the development of the share of yoghurts and other milk products consumption can be seen as positive. There occurs 6% increase during the analysed period. The share of the liquid milk consumption fell down by about 7%.

The Marshallian demand functions estimations (Table 3) describe the Slovak households demand for milk and milk products with respect to the commodity price and households money income

The estimated models of the Marshallian functions of demand for milk and milk products fit the data well (Table 4). 95% to 99% of the total variation in dependent variable (quantity of the demanded milk and milk products) is explained by the variation in independent variables (price and money income), resp. by the multiregression equation for each income quartile. All coefficients, except the coefficient b_1 in 4th quartile, are different than zero with 95% confidence at least (*P*-value in Table 4). The tests rejected the presence of heteroscedasticity, multicolinaerity or autocorrelation.

From the coefficients of price and income demand elasticities E_{pd} in Table 3, it can be observed that the quantity demanded by the lowest income group of households (1st quartile) is the most elastic with respect to price and money income. The 10 percentage increase in the price of milk and milk products results in 12.3% decrease in the quantity demanded (elastic demand). On the other hand, the quantity demanded of milk and milk products decreases only by about 7.8% (inelastic demand) in the 4th income quartile households. The demands of all income quartiles of households are inelastic when the income changes (E_{id}). The higher is the money income, the less sensitive is the quantity demanded. In the 1st income quartile, a 10 percentage change in money income results in 7.5% change in the quantity demanded and 0.6% change in the quantity demanded in the 4th income quartile.

Table 3. The estimation of the Marshallian equations for milk and milk products

Marshallian demand equation		$(E_{id}; E_{pd})$
1st quartile	$q_{31} = 141.98 + 0.0014 \times ri_1 - 4.93 \times rp_4$	(0.75; –1.23)
2nd quartile	$q_{32} = 170.63 + 9.5 \times E^{-4} \times ri_2 - 4.97 \times rp_4$	(0.61; –1.11)
3rd quartile	$q_{33} = 193.529 + 6.8 \times E^{-4} \times ri_3 - 5.01 \times rp_4$	(0.50; –1.03)
4th quartile	$q_{34} = 204.49 + 4.8 \times E^{-5} \times ri_{4-3.01} \times rp_4$	(0.06; –0.78)

Source: Statistical Office of the SR, authors' calculations

Table 4. The Marshallian demand model estimation tests – milk and milk products

		1st quartile	2nd quartile	3rd quartile	4th quartile
Adjusted *R*-squared		0.971178	0.951107	0.985183	0.987529
F-statistics		0.000141	0.000529	2.67E-05	1.74E-05
P-value	$b_1(ri)$	0.003582	0.013645	0.003681	0.519363
	$b_2(rp)$	6.43E-05	0.000342	2.61E-05	0.000103
Farrar-Glauber test	12.59159	3.206101	4.769699	5.124885	6.57973
White test	16.91898	7.918475	7.971631	7.929764	7.962912
Durbin-Watson test	0.229; 2.102	2.976556	2.540947	2.698609	2.751746
The most fitted regression model		linear	linear	linear	linear

Source: authors' calculations based on the Statistical Office of the SR data

Modelling the demand for meat, meat products, eggs and fish

The structure of meat consumption in Slovakia does not follow the recommendation of rational nutrition in the long run. The consumption of smoked meat products and sausages shares in the consumption of the food group of meat, meat products, eggs and fish exceed the recommendations mostly. The consumption of pork also exceeds the recommended consumption and from the year 2000 to the year 2007, it increased by about 2%. The consumption of fish did not increase sufficiently. The 2% increase in poultry consumption can be judged as a positive consumption trend.

The Marshallian demand functions estimations (Table 5) describe the Slovak households demand for meat, meat products, eggs and fish with respect to the commodity price and households money income.

The estimate models of the Marshallian functions of demand for meat, meat products, eggs and fish fit the data well (Table 6). 88% to 94% of the total variation in the dependent variable (demand for meat, meat products, eggs and fish) is explained by the variation in independent variables (price and money income), resp. by the multiregression equation for each income quartile. But according to the *P*-value statistics, we cannot reject the all hypothesis $b_1 = 0$ with at least 95% confidence. Coefficient b_1 is not significantly different from the particular independent variable (money income) and has not the explanatory power with at least 95% confidence. The tests rejected the presence of heteroscedasticity, multicolinaerity or autocorrelation.

The high coefficients of price demand elasticity say that the demand for meat, meat products, eggs and fish of the Slovak households is elastic with respect to price. When the average price of this foodstuffs group goes up by about 10%, the demand for meat, meat products, eggs and fish goes down by about 30.06% in the 1st income quartile and 17.7% in the 4th income

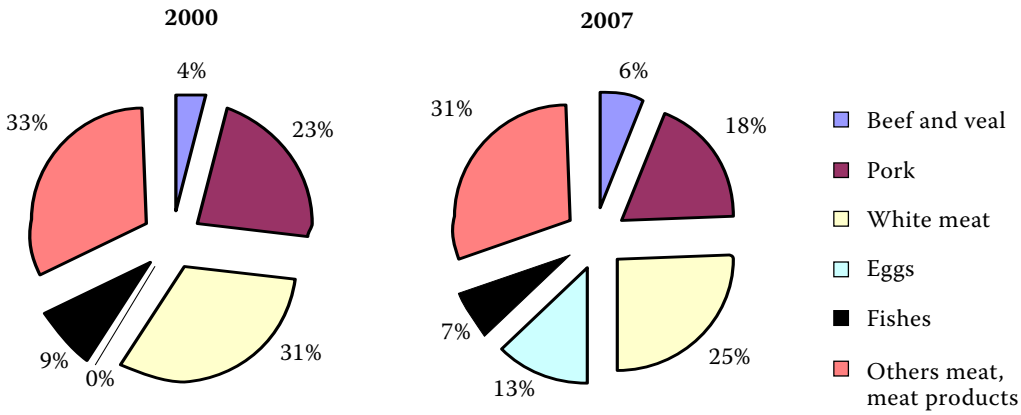

Figure 2. The comparison of the meat, meat products, eggs and fish consumption structures in the year 2000 and 2007

Source: Statistical Office of the SR, authors' calculations

Table 5. Estimation of the Marshallian equations for meat, meat products, eggs and fish

Marshallian demand equation		$(E_{id}; E_{pd})$
1st quartile	$q_{41} = 3\ 258\ 932 \times ri_1^{0.23} \times rp_3^{-3.06}$	(0.23; –3.06)
2nd quartile	$q_{42} = 1\ 375\ 531.3 \times ri_2^{0.23} \times rp_3^{-0.281}$	(0.23; –2.81)
3rd quartile	$q_{43} = 291\ 632.8 \times ri_3^{0.17} \times rp_3^{-2.3}$	(0.17; –2.30)
4th quartile	$q_{44} = 450.89 \times 1.000004^{ri4} \times 0.98^{rp3}$	(0.14; –1.77)

Source: Statistical Office of the SR, authors' calculations

Table 6. The Marshallian demand model estimation tests – meat, meat products, eggs and fish

		1st quartile	2nd quartile	3rd quartile	4th quartile
R-squared		0.961753	0.926189	0.953912	0.916036
Adjusted *R*-squared		0.946454	0.896665	0.935477	0.882451
F-statistics		0.000286	0.00148	0.000456	0.002043
P-value	$b_1(ri)$	0.168773	0.272203	0.187053	0.364779
	$b_2(rp)$	0.002258	0.016464	0.005032	0.029739
Farrar-Glauber test	12.592	4.7843029	5.6035825	5.3495369	6.6175226
White test	16.919	7.9656429	7.9799665	7.8226769	7.8912472
Durbin-Watson test	0.229; 2.102	2.761133	2.9533165	1.9017657	2.2870505
The most fitted regression model		power	power	power	exponential

Source: authors' calculations based on the Statistical Office of the SR data

quartile. The demand for meat, meat products, eggs and fish is the most elastic with respect to price in the whole Healthy Eating Pyramid.

CONCLUSIONS

The aim of the article is to identify the impact of the change in price and money income on the consumption of the selected food groups. There are included two food groups into the analysis. The first group includes milk and milk products, the second one includes meat, meat products, eggs and fish. The criterion for the foodstuffs groups selection is the share of their consumption in the total foodstuffs consumption recommended by the Healthy Eating Pyramid. The recommended consumption share of both food groups is equal to 12.5%. We have verified the hypothesis that their present share in the total food consumption is equal, too, and the sensibility of demand for milk and milk products and demand for meat, meat products, eggs and fish with respect to price and money income is comparable.

The analysis of the present consumption of the individual food groups and the analysis of the price and income elasticities have shown unexpected disproportions and reject the hypothesis formulated. The quantity demanded of meat, meat products, eggs and fish is more price elastic than the quantity demanded of milk and milk products. On the other hand, the demand for milk and milk products is more elastic than demand for meat, meat products, eggs and fish with respect to the change in money income. There was displayed a negative correlation between the level of money income and the value of elasticities. As the money income is higher, the coefficients of price elasticity and income elasticity (sensibility) are lower.

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