APPLICATION OF AR$_{MAX}$ MEASURE FOR ANALYSIS OF FOOD PREFERENCE CHANGES IN ASIAN COUNTRIES 2001-2013

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Abstract: The research of food preferences has, besides a sociological aspect, an economic aspect and is a good starting point for estimating the willingness to incur expenditures on the consumption of individual products. In the paper, the authors compared food preferences on the Asian market for 9 product groups. Due to the complexity of the problem, the study included 17 selected countries of Central and Southeast Asia (China, Mongolia, Japan, India, Thailand, Indonesia, Kazakhstan, Uzbekistan, Tajikistan, Malaysia, Myanmar, the Philippines, Pakistan, Cambodia, Vietnam, Laos, Sri Lanka). The research was carried out on data from 2001 to 2013 with the use of the methods of gradual data analysis. In some countries there were no major changes in nutrition and food consumption, which can be explained by the stabilized political and socio-economic situation. The best example is Thailand.

Keywords: consumer preferences in Asia, food products, multidimensional data analysis, GCA, ar measure, overrepresentation map, ranking, grouping of objects

**JEL classification:** F6, C43, Q1

INTRODUCTION

In Asian countries, changes in food preferences remain subtle for years, which is a consequence of the tradition, culture and religion. Nevertheless, the spread of supermarket chains throughout the world also has a large impact on changes in the proportion of demand for food products and the diversification of

diets in this region [Reardon at al. 2003; Kuhnlein, Receveur 1996]. Especially rapid growth in the number of supermarkets was observed in the early 2000s in China, Indonesia, Malaysia and Thailand and later in India and Vietnam [Reardon at al. 2010]. Asian agriculture is following an irreversible path leading away from its traditional pre-occupation with cereal crop production, especially rice, towards a production system that is becoming increasingly commercialized and diversified [Prabhu 2007]. In South-East Asian countries, the nutrition transition may be due to increasing food availability and food purchasing power rather than to a shift in food preferences towards modern Western foods [Lipoeto 2013]. People in China who live in megacities or highly urbanized neighbourhoods and have higher incomes and educational achievements consume more processed foods [Zhou at al. 2015]. With growing prosperity and urbanization, the per capita rice consumption has started to decline in the middle- and high-income Asian countries, like Japan, Taiwan and the Republic of Korea. However, nearly one-quarter of the Asian population is still poor and has a considerable unmet demand for rice, such as Afghanistan, North Korea, Nepal and Vietnam [Abdullah at al. 2006].

As an example, the differences between the consumption of food products in Thailand in 2001-2003 and that in Thailand in 2011–2013 can be measured. The average of 3 years for both extreme time periods in 9 product groups was taken: x1 - eggs, x2 - fish and seafood, x3 - fruits, x4 - pigmeat, x5 - poultry meat, x6 - rice (milled equivalent), x7 - sugar (raw equivalent), x8 - vegetables and x9 - wheat and products. Such changes take place, although this is a slow process that can only be observed with a significant time interval. In this article, it was decided that a sufficient period for all comparisons is a period of 10 years. For example, in Figure 1, the changes in food preferences in Thailand can be observed. It shows the relative changes in the preferences of the corresponding product groups for the 2 extreme 3-year sub-periods from 2001 to 2013.

Figure 1. Relative changes in the consumption of food products in Thailand between 2011-2013 and 2001-2003
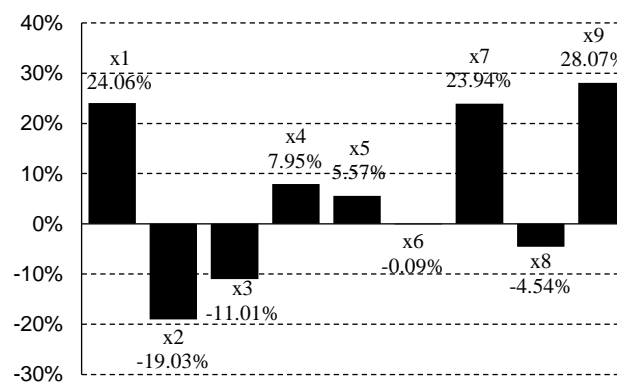
Source: own preparation on the basis of FAO data

According to Figure 1, the most significant changes in Thailand occurred in such products as x1 - eggs, x2 - fish and seafood, x7 - sugar (raw equivalent) and x9 - wheat and products.

METHODS AND DATA SOURCES

The data used in the study come from FAO databases [FAOSTAT 2018] and concern the size of the annual consumption in 17 Asian countries for 9 groups of food products in kg per capita. The study covered the period 2001 - 2013, and consumption was defined as the arithmetic mean of the extreme 3-year time periods. To examine the changes in food preferences for these countries, multidimensional comparative analysis tools were used.

The similarities in the nutrition preferences can be measured on the basis of the measures of the non-similarity of structures that are widely described in the literature [Kowalczyk at al. 2004; Szczesny 2002; Koszela 2016]. The 'sensitivity' of some of these measures, and indeed the lack of certain subtleties, can often be the subject of discussion.

In this paper, an attempt was made to examine the non-similarity of structures in the formulation of the '*ar*' measure, which is one of the tools of grade data analysis. The method of determining this measure is based on the Gini index [Gini 1914; Glasser 1962], which is the doubled field between the diagonal of the square representing the egalitarian distribution and the Lorentz curve [Arnold 1987; Gastwirth 1971; Gini 1914].

To build the 'ar' measure, let us assume that we have two structures:

$$\mathbf{x} = (x_1,\ldots,x_n), \mathbf{y} = (y_1,\ldots,y_n) \in \mathfrak{R}^n_+ \ ,$$

where: $x_i, y_i \geq 0$ and $\sum_{i=1}^{n} x_i = \sum_{i=1}^{n} y_i = 1$

Based on these structures, a broken curve, $L_{[\mathbf{x},\mathbf{y}]}$, can be determined by points that will be cumulative structures of subsequent (in this case) product groups. These points can be defined as follows [Binderman at al. 2014]:

$$P_0 = (0,0), \ P_j = (x_j^\wedge, y_j^\wedge) \ \text{ for } \ j = 1, 2, \ldots, n$$

where: $x_j^\wedge := \sum_{i=1}^{j} x_i$, $y_j^\wedge := \sum_{i=1}^{j} y_i$ and $x_n^\wedge = \sum_{i=1}^{n} x_i = 1, y_n^\wedge = \sum_{i=1}^{n} y_i = 1$

For example, in Table 1, such points were determined for all the product groups, given in a set and natural order from x1 to x9 (in accordance with the designations adopted at the beginning) for food preferences in Thailand, in 2001-2003 and 2011-2013, respectively.

Table 1. Consumption of nine groups of food products and their structures and cumulative structures in Thailand for the period 2001-2013

Product	THA_2001–2003			THA_2011–2013		
	kg/ca	x_i (%)	$\hat{x_j}$	kg/ca	y_i (%)	$\hat{y_j}$
x1	9.84	2.98%	2.98%	12.20	3.71%	3.71%
x2	30.76	9.32%	12.30%	24.91	7.57%	11.28%
x3	62.45	18.91%	31.21%	55.57	16.89%	28.17%
x4	12.03	3.64%	34.85%	12.99	3.95%	32.12%
x5	12.09	3.66%	38.51%	12.76	3.88%	36.00%
x6	113.85	34.48%	72.99%	113.75	34.58%	70.58%
x7	30.63	9.28%	82.27%	37.96	11.54%	82.11%
x8	49.49	14.99%	97.26%	47.24	14.36%	96.47%
x9	9.06	2.74%	100.00%	11.60	3.53%	100.00%
Total	330.19	100.00%		328.98	100.00%	

Source: own calculations

The broken curve $L_{[\mathbf{x},\mathbf{y}]}$, defined by points with coordinates $\left(\hat{x_j}, \hat{y_j}\right)$, is shown in Figure 2.

Figure 2. Broken curve L[x,y] of cumulative structures for 9 food products in Thailand in 2001-2003 and 2011-2013
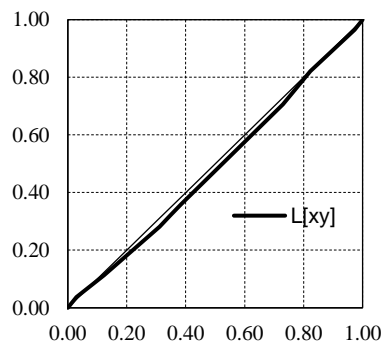
Source: own preparation

The curve $L_{[\mathbf{x},\mathbf{y}]}$ uniquely defines a certain non-fragmentary linear function, $C_{[\mathbf{y}::\mathbf{x}]}(t)$. The function is the basis for determining the *ar* measure of differentiation for the two considered (for the ordered data) structures, x and y:

$$ar(\mathbf{y} : \mathbf{x}) = ar\left(C_{[\mathbf{y}:\mathbf{x}]}\right) = 1 - 2\int_0^1 C_{[\mathbf{y}:\mathbf{x}]}(t)dt \qquad (1)$$

Formula (1) shows that the *ar* measure takes values in the range [-1,1] and $ar(\mathbf{y}:\mathbf{x}) = -ar(\mathbf{x}:\mathbf{y})$. In the case of ordering product groups from x1 to x9, the *ar* measure of non-similarity between food preferences in Thailand in 2011–2013 and those in 2001–2003 is 0.033. Because the value of the *ar* measure is determined by the course of the broken L, and the shape of this broken curve is determined by co-ordinate points that are the accumulation of consecutive structures, it is natural that, depending on the order that we assign to individual food product groups, the *ar* measure will change. Figure 3 shows two different broken lines. Curve L1 is designated (as in Figure 2) according to the order of the constituent structures from x1 to x9 (see Table 1), and the broken L2 is determined in accordance with another, random order of these components.

Figure 3. Polylines L1 and L2 of the cumulative structures for nine groups of food products in Thailand in 2001-2003 and 2011-2013 for two different arrangements of these structures
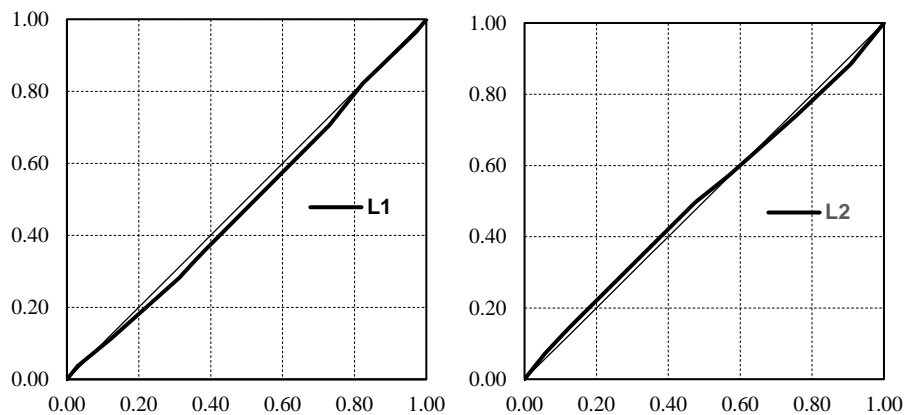
Source: own preparation

Polylines L1 and L2 have different shapes, although they are designated on the basis of the same data set (in this case, data on dietary preferences in Thailand in 2001-2003 and 2011-2013, respectively). The shape of the broken L1 and L2 is determined only by the order in which the individual product groups are given. This order determines the coordinates of points $\left(x_j^{\wedge}, y_j^{\wedge}\right)$ (being the accumulation of consecutive partial structures) that allow us to draw the broken curves (see Table 2).

Table 2. Structures of yearly consumption for nine groups of food products and their cumulative values in Thailand in 2001-2003 and 2011-2013 for two different orderings of the data

Lp.	Polyline L1					Polyline L2				
	Product	THA_2001–2003		THA_2011–2013		Product	THA_2001–2003		THA_2011–2013	
		x_i	$x_j^{\,\wedge}$	y_i	$y_j^{\,\wedge}$		x_i	$x_j^{\,\wedge}$	y_i	$y_j^{\,\wedge}$
1	x1	2.98%	2.98%	3.71%	3.71%	x9	2.74%	2.74%	3.53%	3.53%
2	x2	9.32%	12.30%	7.57%	11.28%	x1	2.98%	5.72%	3.71%	7.24%
3	x3	18.91%	31.21%	16.89%	28.17%	x4	3.64%	9.37%	3.95%	11.18%
4	x4	3.64%	34.85%	3.95%	32.12%	x5	3.66%	13.03%	3.88%	15.06%
5	x5	3.66%	38.51%	3.88%	36.00%	x6	34.48%	47.51%	34.58%	49.64%
6	x6	34.48%	72.99%	34.58%	70.58%	x2	9.32%	56.82%	7.57%	57.21%
7	x7	9.28%	82.27%	11.54%	82.11%	x3	18.91%	75.74%	16.89%	74.10%
8	x8	14.99%	97.26%	14.36%	96.47%	x8	14.99%	90.72%	14.36%	88.46%
9	x9	2.74%	100.00%	3.53%	100.00%	x7	9.28%	100.00%	11.54%	100.00%

Source: own preparation

The consequence of the different courses of the two broken polylines are the different values of the non-similarity of the structures' *ar* measures determined in accordance with formula (1). In the case of polyline L1, the non-similarity *ar* index is equal to 0.033 (as mentioned earlier), while the same index determined for polyline L2 is equal to -0.010. The change of order assigned to individual constituent structures (in this case, food product groups) decides the value (and even the sign) of the non-similarity measure. Therefore, if we want to compare the magnitude of changes in food preferences in a given country (e.g. Thailand, as shown in Table 2), the following question arises: 'For which order of constituent structures should such non-similarity be measured?' This question becomes even more valid if we want to compare the magnitude of these changes between individual countries. In this case, the best solution seems to be to find the right order of the individual components that will ensure such a course of broken curve L, on the basis of which the *ar* index of non-similarity of structures determined in accordance with formula (1) will reach its maximum value. The arrangement of the constituent structures ensures the sorting of food products in non-descending order of the ratio of corresponding structures, y_i to x_i (see Figure 4). The polyline is named L_max, and the measure of the non-similarity of structures determined for this broken curve is called ar_{max} in the literature [Szczesny 2002; Borkowski, Szczesny 2005]. Figure 4 shows the broken L_max and the ordering of the structures allowing such a broken curve to be designed for Thailand in the 2 extreme 3-year time periods for the considered interval.

Figure 4. Broken curve L_max of the cumulative structures of nine food product groups'
             consumption in Thailand in 2001-2003 and 2011-2013

No.	Product	Polyline L_max				
		THA_2001-2003		THA_2011-2013		y_i/x_i
		x_i	$x_j^{\^}$	y_i	$y_j^{\^}$	
1	x2	9.32%	9.32%	7.57%	7.57%	0.813
2	x3	18.91%	28.23%	16.89%	24.46%	0.893
3	x8	14.99%	43.22%	14.36%	38.82%	0.958
4	x6	34.48%	77.70%	34.58%	73.40%	1.003
5	x5	3.66%	81.36%	3.88%	77.28%	1.060
6	x4	3.64%	85.00%	3.95%	81.22%	1.083
7	x7	9.28%	94.28%	11.54%	92.76%	1.244
8	x1	2.98%	97.26%	3.71%	96.47%	1.245
9	x9	2.74%	100.00%	3.53%	100.00%	1.285
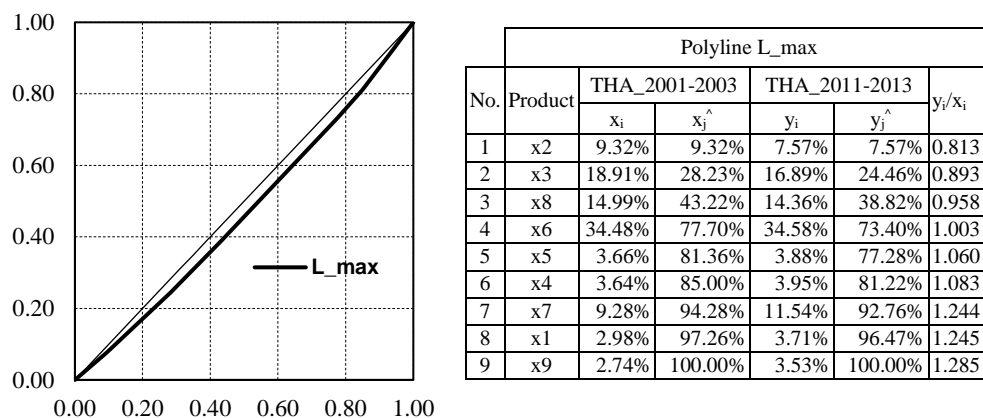
Source: own preparation

The ar index (based on formula 1) calculated on the basis of the broken
L_max is equal to ar$_{max}$ = 0.066. This is the largest possible non-similarity value
that can be obtained by comparing Thailand in 2011-2013 with Thailand in 2001-
2003. Measures of the non-similarity ar through appropriate rank of food products
groups for individual countries, are maximized, creating a new measure of ar$_{max}$.
On the basis of the measures of ar$_{max}$ treated as the largest possible dissimilarity,
the ranking of countries is created in terms of the size of changes in food
preferences. Classical measures (e.g. Minkowski's measure) due to they
insensitiveness to the order, measure only the distance between countries, which
does not give full information about the countries non-similarities in terms of all
studied features. Therefore, a method based on the ar$_{max}$ measure has been chosen.

RESULTS

To compare the magnitude of changes in food preferences in Asia over the
10 evaluated years, ar$_{max}$ indicators can be determined separately for each country
studied, enabling the comparison of the consumption of 9 selected food product
groups in the 3-year extreme periods, specifically 2001-2003 and 2011-2013. The
ar$_{max}$ as non-similarity indicators for the 17 surveyed Asian countries are shown in
Table 3.

Table 3. Indices of the non-similarity of the structures' ar$_{max}$ as a measure of the size
            of changes in food preferences in Asian countries in 2001-2013
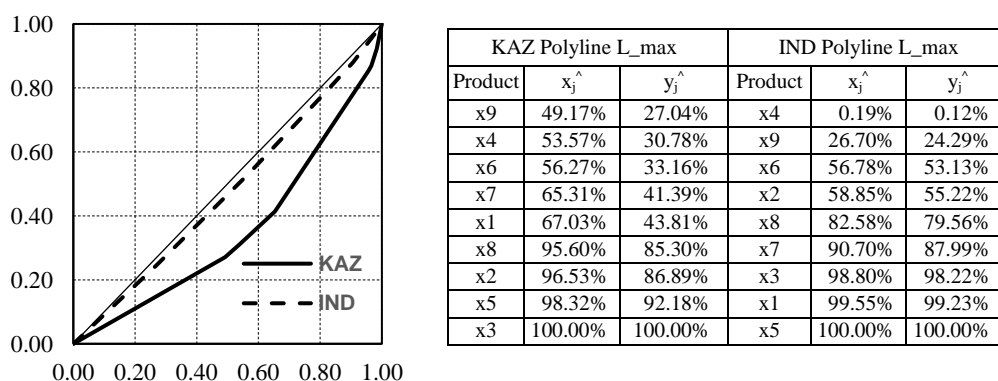
	Rank	Country	Code	ar$_{max}$
GR1	1	Kazakhstan	KAZ	0.293
	2	Uzbekistan	UZB	0.224
	3	Myanmar	MMR	0.202

	Rank	Country	Code	ar_{max}
	4	Tajikistan	TJK	0.193
	5	Viet Nam	VNM	0.151
GR2	6	Mongolia	MNG	0.132
	7	Sri Lanka	LKA	0.096
	8	Malaysia	MYS	0.093
	9	Lao People's DR	LAO	0.088
	10	China	CHN	0.077
	11	Philippines	PHL	0.076
	12	Japan	JPN	0.073
GR3	13	Indonesia	IDN	0.072
	14	Thailand	THA	0.066
	15	Cambodia	KHM	0.064
	16	Pakistan	PAK	0.057
	17	India	IND	0.050

Source: own calculations with the use of GradeStat software

In this case, the determined ar_{max} indices can be treated as synthetic indicators showing the size of changes in dietary preferences in the examined time period. It should be kept in mind that the largest possible non-similarity value (ar_{max}) for each country was calculated, which is related to the different ordering of product groups for each country. The ar_{max} indicators calculated for each country allow the creation of a ranking of countries with the largest changes in nutrition preferences. It can be noticed that the largest changes took place in Kazakhstan and the smallest in India. Figure 5 shows the broken curves L_{max} for both countries. To complement the figure, next to the broken lines for both ar_{max} measures are shown the orderings of the product groups and the coordinates of the points by which the polylines were determined ($x_j^{\wedge}$ - cumulative structures in the period 2001–2003; $y_j^{\wedge}$ - cumulative structures in the period 2011–2013).

Figure 5. Polylines L_max of the cumulated consumption structures of nine groups of food products for Kazakhstan and India

| KAZ Polyline L_max			IND Polyline L_max		
Product	$x_j^{\wedge}$	$y_j^{\wedge}$	Product	$x_j^{\wedge}$	$y_j^{\wedge}$
x9	49.17%	27.04%	x4	0.19%	0.12%
x4	53.57%	30.78%	x9	26.70%	24.29%
x6	56.27%	33.16%	x6	56.78%	53.13%
x7	65.31%	41.39%	x2	58.85%	55.22%
x1	67.03%	43.81%	x8	82.58%	79.56%
x8	95.60%	85.30%	x7	90.70%	87.99%
x2	96.53%	86.89%	x3	98.80%	98.22%
x5	98.32%	92.18%	x1	99.55%	99.23%
x3	100.00%	100.00%	x5	100.00%	100.00%

Source: own preparation

Due to the fact that Kazakhstan and India occupy two extreme positions in the ranking created (respectively first and last in Table 3), it can be observed that the broken curve L_max created for India is practically coincident with the diagonal of the square. This represents evidence of a negligible degree of change in the Indian food preferences comparing the period 2011-2013 with the period 2001-2003. The reverse situation concerns the broken curve L_max for Kazakhstan. Its course clearly deviates from its diagonal shape, showing a clear change in the menu choices of Kazakhs in the studied period. Determining the ar$_{max}$ indicators of the non-similarity and treating them as a synthetic variable, apart from creating a ranking, allows for the division of countries into groups in terms of the size of changes in food preferences. This study uses a simple division into three groups (see Table 3) based on the average deviation, in which the first group includes the largest, the second group a moderate and the third a negligible change in nutrition preferences.

Figure 6 shows the changes in preferences that occurred in the country that was the leader of the ranking - Kazakhstan.

Figure 6. Relative changes in the consumption of food products in Kazakhstan between 2011-2013 and 2001-2003
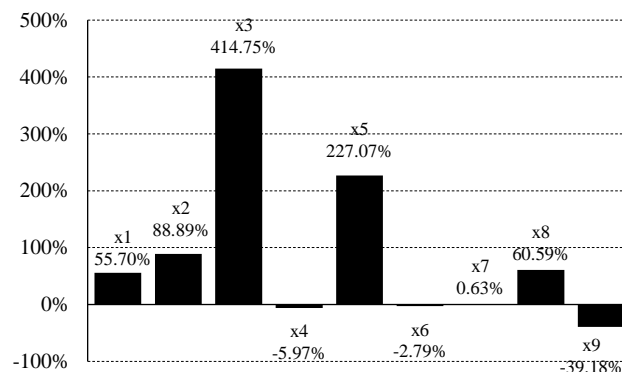
Source: own preparation

CONCLUSIONS

In spite of rapid economic growth, urbanization and globalization leading to a shift of Asian diets away from staples and towards livestock and dairy products, fruits, vegetables, fats and oils, there are many traditional reasons that slow this trend down and prevent quick changes. The countries where the changes in food preferences were the faintest are India, Pakistan and Cambodia – the least wealthy countries in the studied group. While the diversification of diets away from the traditional dominance of rice with rising incomes is expected and observed in Asia and current food consumption patterns are showing signs of convergence, there are

still countries where the food preferences are rather stable over the years. However, this situation may change in the future, because as a consequence Asian agriculture is following an irreversible path leading away from its traditional cereal crop production, especially rice. On the other side, Kazakhstan and Uzbekistan (formerly the Republic of USSR) changed their food nutrition patterns the most during the period of time analysed. The diet transition in those countries is characterized by increased consumption of fruit, poultry, fish and vegetables and relatively decreased consumption of pigmeat and rice. The rapid spread of global supermarket chains and fast-food restaurants is reinforcing those trends. Those changes can influence the global market and the world economy and can lead to reversed directions of imports and exports of goods in Asian countries and Europe. The methods of grade state analysis were very useful in emphasizing subtle changes in food product preferences that occurred over 10–13 years. Dividing countries into groups, the group with the most changes was identified as consisting of Kazakhstan, Uzbekistan, Myanmar, Tajikistan and Vietnam. In the second group, with moderate changes, appeared Mongolia, Sri Lanka and Malaysia. The fewest changes in food preferences occurred in Lao People's Democratic Republic, China, the Philippines, Japan, Indonesia, Thailand, Cambodia, Pakistan and India.

REFERENCES

Abdullah A. B., Ito S., Adhana K. (2006) Estimate of Rice Consumption in Asian Countries and the World Towards 2050. [in:] Proceedings for Workshop and Conference on Rice in the World at Stake. 2, 28-43.

Arnold B. C. (1987) Majorization and the Lorenz Order: A Brief Introduction, Lecture Notes in Statistics, 43. Springer-Verlag, Berlin.

Binderman Z., Koszela G., Szczesny W. (2014) Zmiany w strukturze gospodarstw rolnych w krajach Unii Europejskiej w latach 2003-2010 (aspekty metodyczne). Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie, Problemy Rolnictwa Światowego, 14(3), 15-26 (in Polish).

Borkowski B., Szczesny W. (2005) Metody wizualizacji danych wielowymiarowych jako narzędzie syntezy informacji. Roczniki Naukowe, Seria VII, 5, 11-15 (in Polish).

FAOSTAT. http://www.fao.org/statistics/en/.

Gastwirth J. L. (1971) A General Definition of the Lorenz Curve. Econometrica, 39(6), 1037-1039.

Gini C. (1914) Sulla Misura Della Concentrazione e Della Variabilità dei Caratteri, Atti del R. Istituto Veneto di Scienze Lettere ed Arti.

Glasser G. J. (1962) Variance Formulas for the Mean Difference and Coefficient of Concentration. Journal of the American Statistical Association, 57.

Koszela G. (2016) Wykorzystanie narzędzi gradacyjnej analizy danych do klasyfikacji podregionów pod względem struktury agrarnej. Wiadomości Statystyczne, 6, 10-30 (in Polish).

Kowalczyk T., Pleszczyńska E., Ruland F. (Eds.) (2004) Grade Models and Methods of Data Analysis. With Applications for the Analysis of Data Population. Studies in Fuzziness and Soft Computing, 151. Springer, Berlin - Heidelberg - New York.

Kuhnlein H. V., Receveur O. (1996) Dietary Change and Traditional Food Systems of Indigenous Peoples. Annual Review of Nutrition, 16(1), 417-442.

Lipoeto NI., Geok Lin K., Angeles-Agdeppa I. (2013) Food Consumption Patterns and Nutrition Transition in South-East Asia. Public Health Nutrition, 16(9), 1637-1643, doi: 10.1017/S1368980012004569.

Prabhu P. (2007) Westernization of Asian Diets and the Transformation of Food Systems: Implications for Research and Policy. Food Policy, 32(3), 281-298.

Reardon T., Timmer P. C., Barrett Ch. B., Berdegué J. (2003) The Rise of Supermarkets in Africa, Asia, and Latin America. American Journal of Agricultural Economics, 85(5), 1140-1146, https://doi.org/10.1111/j.0092-5853.2003.00520.x.

Reardon T., Timmer P., Minten B. (2010) Supermarket Revolution in Asia and Emerging Development Strategies to Include Small Farmers. Proceedings of the National Academy of Sciences, doi: 10.1073/pnas.1003160108.

Szczesny W. (2002) Grade Correspondence Analysis Applied to Contingency Tables and Questionnaire Data. Intelligent Data Analysis, 6(1), 17-51.

Zhou Y., Du S., Su C., Zhang B., Wang H., Popkin BM. (2015) The Food Retail Revolution in China and its Association with Diet and Health. Food Policy, 55, 92-100, https://doi.org/10.1016/j.foodpol.2015.07.001.