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Quantitative Analysis of European Union Agriculture Performance

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Abstract

The main aim of the article is to analyze differences of agriculture performance across the European Union countries in the years 2010-2013. The special attention was devoted to the results obtained by New Member States. The research was conducted with application of multiple criteria analysis tools: the method proposed by Hellwig and Ward's clustering method. The research was based on the collection of the World Bank development indicators. It confirms the existence of significant disparity in the performance of agricultural sector between the old and new member states that joined the UE after the year 2004.

Keywords: *Multiple Criteria Decision Analysis (MCDA), Hellwig Method, Cluster analysis, Economic performance, Agriculture*

JEL Classification: C38, O13

Introduction

The creation of common agriculture policy has been one of the main objectives of the European Union funders. For five decades the expenditures devoted to its realization have made the biggest position in the EU budget. In recent years Common Agriculture Policy (CAP) has been significantly reformed. As a result, with liberalization of agricultural trade, the sector has been moved to market orientation and less protection (Giannakis & Bruggeman, 2015). However, an important objective of the CAP is still to mitigate differences in performance of agricultural sector between the EU members. Additionally, in spite of the liberalization process agricultural sector is also considered as a sphere of strategic interest of the EU and individual European governments both in the case of such big agricultural producers among old member states like France, Spain or Italy, but also new member states like Poland. As a result, the research on economic performance of European agriculture should be considered as an important field of interests.

Therefore, in the article comparison of economic performance of agricultural sectors in the EU member states is performed. The research is conducted for the years

2010-2013. The first year of the research was chosen as it had been more than five years since the biggest European Union enlargement, which can be considered as a minimum time necessary for adjustment of agricultural sector of Central European countries. The year 2013 makes the last year, where the data is available for the whole set of countries under evaluation.

In the article two main scientific aims are given. First goal of the research is to propose a method of comparing economic performance of agricultural sector at national level. In this context, multiple criteria decision analysis (MCDA) methodology is applied. A ranking of countries was done with application of method proposed by Hellwig. As a second objective of the article, authors try to identify group of countries that are similar to each other, but different from other groups of countries based on studied characteristics. For this purpose cluster analysis with application of Ward's method was used.

In the first part of the paper a review of previous research on the effectiveness of European agriculture is given with special consideration to the research, where the effectiveness of agriculture was treated as a complex and multivariate phenomenon. The second section is devoted to the presentation of the applied methodology. The third part of the paper has strictly empirical character. First a ranking of countries was proposed, which was supplemented with cluster analysis. The article is closed with short conclusions.

Review of previous research

The impacts of the EU enlargement and influence of the Common Agricultural Policy reforms measured by various agricultural performance measures have been the topics of profound research with application of quantitative methods both at aggregate macroeconomic and microeconomic level.

Latruffe (2010) reviews the literature on competitiveness, productivity and efficiency in the agricultural and agri-food sectors. The author clarifies concepts and terminology used in this area, and provides a critical assessment of approaches and indicators used in the literature to measure competitiveness, productivity and efficiency at sectorial and farm levels.

Dos Santos (2013) characterizes and segments the farms of the twenty-seven member states of the European Union. For this purpose, she adopted the technique of cluster analysis and clustering cases using segments of the farms, based on a sample of farms of the Farm Accountancy and Information. The results show the existence of four types of farms in the EU that are distinguishable by their structural characteristics, financial characteristics, and guidance and the importance of subsidies.

Spicka (2013) investigates the differences of farm income and its determinants between the old- (EU-15) and the new EU member states (EU-12) before and after EU enlargements during 2001–2011. With cluster analysis the specific structural and economic features within the EU are identified. Author concludes that the rankings of the EU-27 countries changed after the EU enlargement. However, the European countries with highly intensive agriculture still rank the top positions. For example, the average labor input in the EU-12 is substantially higher than in the EU-15. This fact, together with the lower fixed capital consumption, points to the lower level of the technical equipment and farming technologies in the EU-12.

Carraresi and Banterle (2015) evaluates the EU countries' competitive performance at a sectorial level in the intra-EU market from 1995 to 2011 by comparing the food industry and agriculture; and assessing the effects of the EU expansion and economic crisis on country competitiveness. Results showed that although agriculture and the food industry in the EU are interconnected, they often reveal divergent trends in competitive performance. Germany and the Netherlands have profited the most from the opportunities resulting from the enlargement. On the contrary, France has lost competitiveness. A similar trend was found in Belgium.

Giannaskis and Bruggeman (2015) investigate the factors that lie behind the differential performance of agriculture across the twenty-seven EU countries, based on gross-value-added and land and labor productivity indicators. Significant differences were revealed between the Northern-Central counties and the continental peripheries (Mediterranean, Eastern, and Northern Scandinavian). Authors have analyzed the factors behind this differential performance as human capital characteristics, environmental conditions and technical efficiency of crop production. Agricultural sectors characterized by a young and better trained farm population are more likely to attain high economic performance. On the other hand, the wheat and tomato yield variables highlight the importance of both environmental conditions and technical efficiency on farm economic performance.

Szabo and Grznár (2015) ranked individual EU countries according to the long-term average of the amount of their agricultural produce per unit of area into seven segments. Conducted analysis showed strong links between the production and the fixed and variable assets, the levels of livestock, and the provided supports. The size of a business and the availability of labor force did not appear to have a significant influence on the performance of an average business in a country.

Svoboda *et al*. (2015) compare agricultural subsidies in the member states of the EU during 2004-2012 based on the database Farm Accountancy Data Network. The authors conclude that there has been a slight increase in operational subsidies. With the help of cluster analysis, the member states were divided into groups according to their operational subsidies, total production, and costs.

Pietrzak and Walczak (2014, 2016) proved that the agrarian structure is one of the most important determinants of the development of agriculture in Poland. Ineffective agrarian structure with low concentration of land makes significant barrier to the development of agriculture due to high production costs and generation of low income. In the research the authors applied spatial statistical measures and the Gini coefficient.

Due to the fact that effectiveness of agricultural sector is influenced by multivariate factors, in the case of the cited literature quantitative research was usually conducted with application of MCDA methods or cluster analysis. As a result, the study proposed in the current paper can be also placed in that methodological approach. It concentrates on the aggregate macroeconomic level.

Research Methodology: Multiple Criteria Analysis

Most of economic phenomena can be characterized as complex and multivariate factors from the perspective of description or quantification (Balcerzak, 2009; 2015; Biczkowski, *et al*. 2014; Pietrzak, *et al.* 2014; Jantoń-Drozdowska, and Majewska, 2015, 2016; Zielenkiewicz, 2014, 2015; Balcerzak and Pietrzak, 2015; 2016a, 2016b, 2016c, 2016d, 2016e; 2016f; 2016g, Pietrzak and Balcerzak, 2016a). As a result multiple criteria decision making (MCDM) or multiple criteria decision analysis (MCDA) methodology are currently commonly used in international comparative studies (Kuc, 2012a; Mościbrodzka, 2014; Jurkowska, 2014; Łyszczarz, 2016; Jurkowska, 2014; Balcerzak, 2011a, 2017).

Multiple criteria analysis methods can be divided into two groups. The first group allows to carry out ordering of objects from the worst to the best from the perspective of analyzed complex phenomena. Taxonomic measure of development proposed by Hellwig (Renigier-Biłozor and Biłozor, 2015; Pietrzak and Balcerzak, 2016b), which is applied in this article, can be found in this group. The second group of methods allows to classify analyzed objects to homogeneous subsets, where the objects are characterized with similar values of the features. In this group one can find cluster analysis with Ward's method as an example (Ward, 1963; Murtagh and Legendre, 2014; Kuc, 2012b, Balcerzak *et al*., 2008).

It should be emphasized that multiple criteria decision analysis methods provide useful tools, which can be effectively used not only in decision making process, but they can be universally applied in economic research. Their main advantage lies in their high cognitive values in explaining complex economic reality and their great application flexibility. These tools can be used to analyze most of economic phenomena. Additionally, the research can concentrate on any economic objects within the framework of undertaken problem.

Taxonomic measure of development proposed by Hellwig

The concept of taxonomic measure of development (TMD) was proposed by Zdzisław Hellwig in 1968 (Hellwig, 1968, 1972; see Balcerzak, 2016a). The application of TMD allows to order analyzed objects (for example countries) based on the level of development of the phenomenon under evaluation. In order to use this measure the analyzed phenomenon is broken on the separate economic aspects, each of which describes a different part of the economic system. For each aspect a set of diagnostic variables that characterize the aspect and allow its description is selected. Then, based on the accepted diagnostic variables a synthetic variable (taxonomic measure of development) is calculated. It takes into account the impact of all determinants of examined economic phenomenon and allows to evaluate its level. The use of TMD in a spatial economic analysis enables to assess the current situation of the objects under study and to make their ranking from the worst to the best.

The procedure for obtaining TMD can be given in the following steps (Balcerzak, 2016a; 2016b; Balcerzak and Pietrzak, 2016e):

1. The research problem should be determined. Then, the examined phenomenon, a set of analyzed objects O_i and a set of variables Z_j characterizing the phenomenon should be adopted.
2. The diagnostic variables Z_j should be standardized in order to obtain their comparability. As a result, standardized variables S_j are obtained.
3. In the next step a pattern of development W_j is determined. In the case of stimulants it is chosen in accordance with the principle of maximum value selection and opposite in the case of dis-stimulants. The stimulants can be defined as variables that support economic development of the phenomenon under evaluation and the dis-stimulants are the once that hamper it.
4. Then, with application of Euclidean distance for every i-object one should find distances d_i from the pattern of economic development W_j.
5. In the last stage the value of TMD_i for every i-object can be determined based on equation 1.

$$TMR_i = 1 - \frac{d_i}{d_s + 2s_d}, \qquad (1)$$

where TMR_i is the value of the measure for object O_i , d_i is Euclidean distance of i-object form the pattern of development, d_s is an average distance of objects form the pattern of development, s_d makes standard deviation of distances of the objects from the pattern of development.

TMD_i determined in accordance with the described procedure is a normalized measure, which in most cases has values from zero to unity. Higher values of the measure indicate positive trends in the development of the examined phenomenon.

Cluster analysis

Cluster analysis is a multivariate statistical technique that entails division of large group of objects into smaller and more homogeneous groups – clusters. In general terms, cluster analysis works with *N* statistical objects while *k* statistical characteristics are observed and measured. Clustering methods are based on similarity, respectively dissimilarity of the objects and based on these objects, data points are divided into clusters, which are mutually disjunctive. The objects assigned to every cluster are similar to each other in terms of the level of adopted variables. For the purpose of this paper agglomerative hierarchical clustering Ward's method (Ward, 1963) has been conducted, as it has been the most commonly used method in studies reviewed. Ward's method is based on least-squares criteria and minimizes the within-cluster sum of squares, thus maximizing the within-cluster homogeneity (Everitt et al., 2011). In this method, in the first stage of clustering, each analyzed object is considered as individual cluster and subsequently, these objects are grouped to superior cluster, which are grouped again based on the distance between them, while the objects with the smallest distance between are grouped together. On the highest level of clustering, all the statistical objects are joined into one cluster. For measurement of the distance between the objects the metric of Euclidian distance can be used

The process of Ward's method has an iterative character. It is repeated until each of all the clusters is formed into a single massive cluster.

The results of hierarchical clustering can be viewed through development tree or dendrogram. The root of the dendrogram represents the whole data set. The nodes within dendogram describe the extent to which the object relates. The results of the cluster analysis are dendrograms obtained by cross-section at different levels (Ward, 1963; Ivaničová, Kalužák, 2015; Reiff and Surmanová, 2016; Małkowska & Głuszak, 2016; Balcerzak, 2011b, 2011c).

Economic performance of agricultural sector of EU countries

The characterized multiple criteria analysis methods were applied for comparative research on economic results of agricultural sector of the EU countries in the years 2010-2013. The research was conducted for 24 European Union member states. Luxemburg, Malta, Cyprus and Croatia were excluded from the research due to specific character of these economies, where truism, financial sector or production of luxurious goods have dominant role in GDP creation. In the same time agricultural sector has rather marginal role in these economies.

As it was presented in the review of previous research the economic performance of agricultural sector can be considered as multivariate phenomenon. Thus, in order to describe it, 6 diagnostic variables were used. The diagnostic variables with classification of their character and descriptive statistics are given in Table 1. The variables X_1 to X_5 can be classified as stimulants. Their high values indicate higher effectiveness of agricultural sector of a given country. From the macroeconomic perspective last variable X_6 can be treated as dis-stimulant. From the perspective of developed industrial or knowledge-based economies high agriculture value added as a percentage of GDP can indicate ineffective structure of economy. In the case of highest developed economies high services and industrial production value added as a percentage of GDP is a standard.

The research is based on World Bank data. The data utilized for mulitiple criteria analysis were averaged across four year reference period (2010–2013) to mitigate specific effect in particular years, caused by fluctuations either in production due to for example bad weather conditions or in input, output prices on the world markets (Reiff and Surmanová, 2016).

Table 1. Summary statistics of selected variables

Variable	Character	Mean	Median	Minimum	Maximum	Standard Deviation	Coefficient of Variation
X_1 - Crop production index (2004-2006 = 100)	Stimulant	98,47	96,35	68,23	138,65	15,05	0,15
X_2 - Food production index (2004-2006 = 100)	Stimulant	99,78	100,22	83,72	125,00	10,39	0,10
X_3 - Livestock production index (2004-2006 = 100)	Stimulant	98,83	98,56	81,57	115,99	8,49	0,09
X_4 - Cereal yield (kg per hectare)	Stimulant	5055,64	4917,86	1783,54	9058,98	1745,75	0,35
X_5 - Agriculture value added per worker (constant 2005 US$)	Stimulant	32232,27	25915,64	3158,29	135039,16	28585,62	0,89
X_6 - Agriculture, value added (% of GDP)	Dis-stimulant	2,59	2,28	0,31	6,28	1,45	0,56

Source: own estimation based on World Bank data.

In the first step of the research TMD proposed by Hellwig was determined. Its values enabled to propose ranking of the countries based on economic results of their agricultural sectors. The results are given in Table 2.

The research confirms that more than five years since the biggest EU enlargement significant heterogeneity between old and new members states is still present. The old member states can be considered as the leaders of the proposed ranking. Among the old member states only two Scandinavian countries Sweden and Finland, and two Southern European countries Greece and Portugal are characterized by relatively low level of TMD. To some extend these results should be expected, as the changes in agricultural sector, here improvement its effectiveness in the case of new member states, are usually gradual. On the other hand, among new member states relatively high positions in the proposed ranking were taken by two Baltic countries Estonia and Latvia. The ranking is closed with Central and Southern European economies such as Slovenia, Slovakia, Czech Republic, Poland, Bulgaria, Romania and Hungary.

Table 2. Ranking of the EU countries based on the economic results of agricultural sector

Country	Rank	TMD	Country	Rank	TMD
Netherlands	1	0,593	Lithuania	13	0,276
Belgium	2	0,453	Sweden	14	0,276
France	3	0,431	Slovenia	15	0,269
Denmark	4	0,413	Portugal	16	0,261
Germany	5	0,411	Finland	17	0,257
Austria	6	0,403	Poland	18	0,242
United Kingdom	7	0,369	Bulgaria	19	0,217
Estonia	8	0,326	Czech Republic	20	0,160
Spain	9	0,309	Greece	21	0,100
Latvia	10	0,303	Slovak Republic	22	0,034
Italy	11	0,291	Romania	23	0,033
Ireland	12	0,285	Hungary	24	0,023

Source: own estimation based on World Bank data.

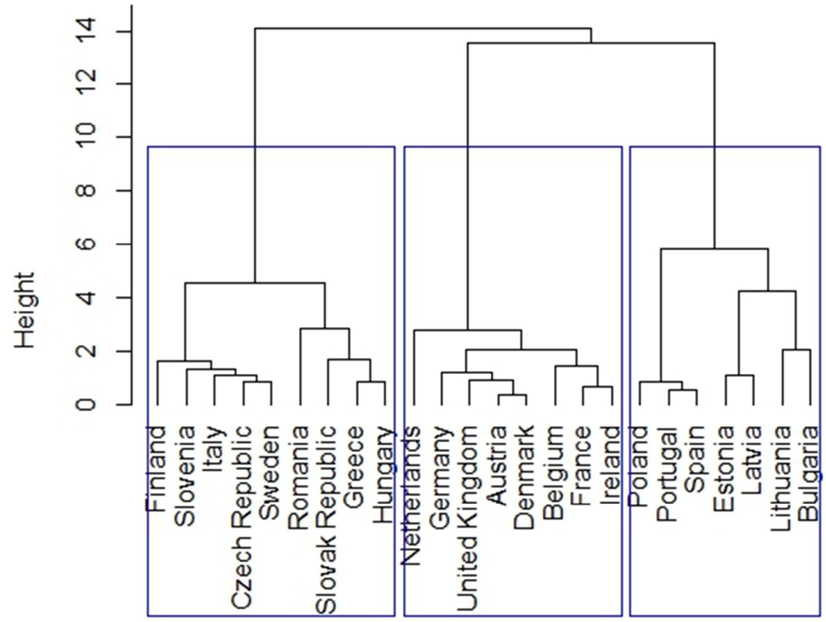
The proposed ranking should be additionally supplemented by pointing the subsets of relatively homogenous countries in relation to the values of the variables used in the analysis. Thus, in further analysis the cluster analysis was applied. The cluster analysis was performed in R-Cran. Ward's method characterized in previous section was applied here.

In the first step three classes of countries (Level 1) were selected based on the dendogram. The results are given in Figure 1 and in Table 3. In the first Class one can find Finland, Romania, Slovenia, Slovak Republic, Italy, Greece, Czech Republic, Hungary, Sweden. In the second Class there are Netherland, United Kingdom, Austria, Denmark, Belgium, France and Ireland. In the third Class the following countries were placed: Poland, Estonia, Lithuania, Portugal, Latvia, Bulgaria and Spain.

A comparison of three selected Classes with the ranking presented in Table 2 shows that within the Classes there are countries that occupy significantly different places in the ranking. For example, in the third Class one can find Latvia and Estonia, which are much higher in the ranking compared to other countries in this Class.

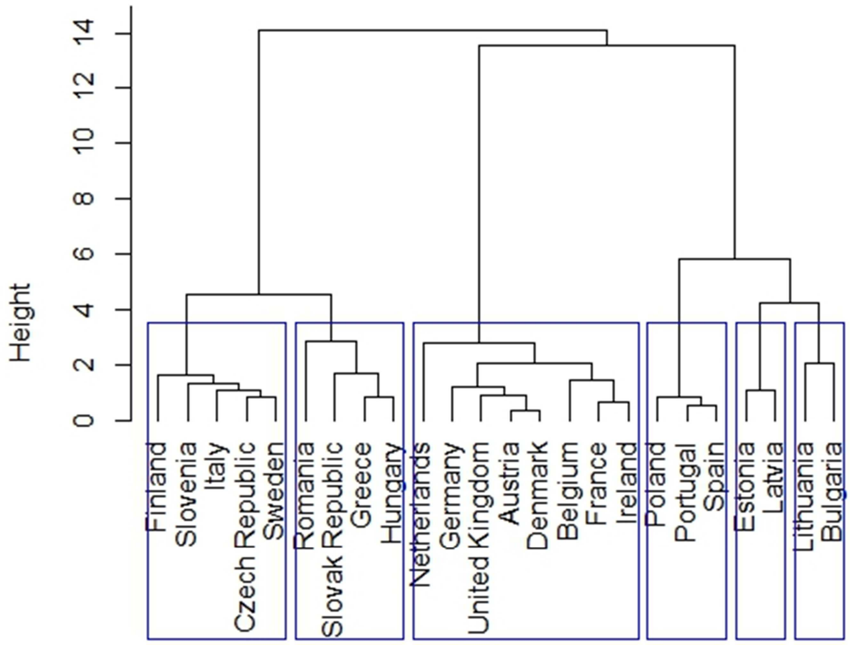
As a result, in the second stage a division of countries into six subsets (Level 2) was assumed. The dendogram with the results are given in Figure 2 and 3 and the Classes of countries are described in Table 3. The comparison of the obtained subsets with the ranking form Table 2 confirms that the assumption of division of the countries into 6 Classes is reasonable. The results of cluster analysis are consistent with application of the method proposed by Hellwig. All the countries in a given Class have relatively close positions in the ranking.

Figure 1. Dendogram presenting three classes based on the variables describing situation of agricultural sector (Level 1)



Source: own estimation based on World Bank data.

Figure 2. Dendogram presenting six classes based on the variables describing situation of agricultural sector (Level 2)



Source: own estimation based on World Bank data.

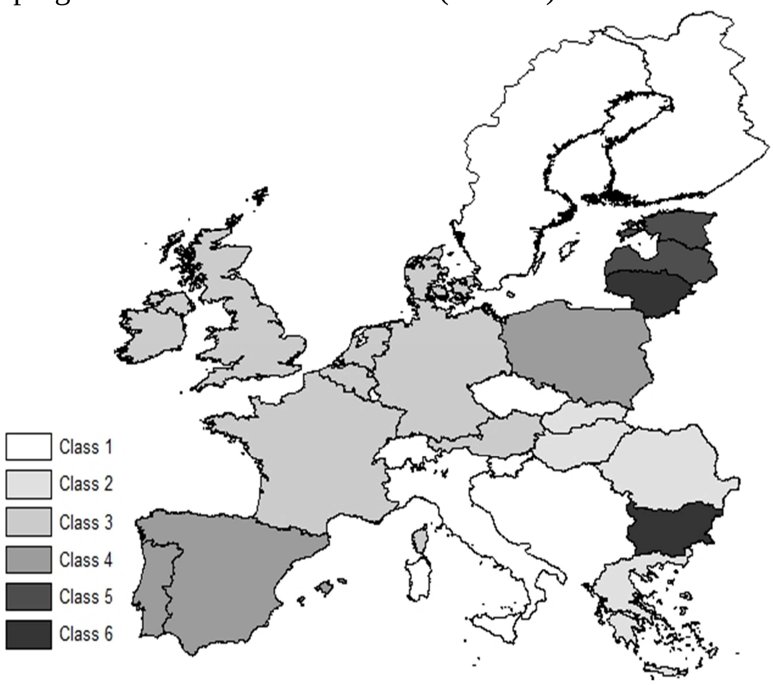
Table 3. Classes of countries based on the dendograms from Figure 1 and 2

Level 1		
Class 1	**Class 2**	**Class 3**
Finland	Netherlands	Poland
Slovenia	Germany	Portugal
Italy	United Kingdom	Spain
Czech Republic	Austria	Estonia
Sweden	Denmark	Latvia
Romania	Belgium	Lithuania
Slovak Republic	France	Bulgaria
Greece	Ireland	
Hungary		

Level 2					
Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Finland	Romania	Netherlands	Poland	Estonia	Lithuania
Slovenia	Slovak Republic	Germany	Portugal	Latvia	Bulgaria
Italy	Greece	United Kingdom	Spain		
Czech Republic	Hungary	Austria			
Sweden		Denmark			
		Belgium			
		France			
		Ireland			

Source: own estimation based on World Bank data.

Figure 3. Grouping of countries into six classes (Level 2)



Source: own estimation based on World Bank data.

In the next step the differences between clusters were verified. To identify indicators that are of a significantly different level in one Class compared to another, the Kruskal-Wallis rank test was used. The Kruskal-Wallis test is a rank-based nonparametric test that can be used to determine for every variable if there are statistically significant differences in an average for determined classes. The application of the test enables to verify if the values of the variables used in the research are significantly different for every class. As the Kruskal-Wallis test does not assume normality in the data and is much less sensitive to outliers, it can be used when these assumptions have been violated. The Kruskal-Wallis rank test was performed for six variables on Class 1, 2 and 3 defined by Level 1 and Class 1, 2, …, 6 defined by Level 2. The results are given in Table 4. The analysis indicates that statistically significant differences between classes at the 0,05 level of significance are seen for all variables in the case of Level 1. In the case of level 2 averages between classes were significantly different for variables: X_1, X_2, X_3, X_4, X_6. The exception here was variable X_5 - Agriculture value added per worker at Level 2. However, in the case of variable X_5 it should be noted that the p-value is 0.0538. Thus, it is on the edge of significance. Raising the level of significance to α = 0.1 would mean that the average for variable X_5 is also significantly different for established groups.

As a conclusion, the results of Kruskal-Wallis test indicate that the variables used in the multiple criteria analysis were selected properly. Their values significantly differentiate determined classes.

Table 4. Results of Kruskal-Wallis Test, Evidence of significant differences in average between Classes at level of significance α=0.05

***p*-value**	X_1	X_2	X_3	X_4	X_5	X_6
Level 1	0,0004	0,0001	0.0012	0,0001	0,0216	0,0006
Level 2	0,0035	0,0015	0.002	0,0016	0,0538	0,0011

Source: own estimation.

In the last step, for each of 6 classes (Level 2) an average values of the variables used to assess the effectiveness of agricultural sector were calculated. The average values for the variables allow to describe the main determinants of the position of the countries assigned to each class. The results are given in Table 5.

Table 5. Average values of variables applied for multi criteria analysis of UE agriculture (Level 2)

Class	X_1	X_2	X_3	X_4	X_5	X_6
Class 1	92,834	93,162	93,212	4877,046	57775,506	2,185
Class 2	85,764	87,689	89,151	4200,167	12783,462	4,386
Class 3	98,479	103,459	104,409	7274,908	43090,851	1,272
Class 4	102,744	103,604	103,643	3670,599	16178,440	2,660
Class 5	127,203	122,148	115,691	3031,042	8596,244	3,739
Class 6	126,720	112,426	94,184	3733,947	12732,635	4,561

Source: own estimation.

In the ranking the highest positions are occupied by countries form class 3, Netherland, United Kingdom, Austria, Denmark, Belgium, France and Ireland, which are characterized by a high level of agriculture value added per worker (variable X_5) and the lowest share of agriculture value added in GDP (variable X_6).

Relatively high positions in the ranking are taken by the countries form class 5: Estonia and Latvia that have the highest levels of the variables X_1, X_2 and X_3, which confirms relative high performance of their agricultural sectors. However, in the same time these countries are characterized with the lowest level of agriculture value added per worker (variable X_5), which indicates relatively low labor productivity of their agriculture.

On the other hand, the highest level of agriculture value added per worker can be seen in the case of countries in class 1: Finland, Slovenia, Italy, Czech Republic and Sweden. In the same time these countries are characterized by a low level of variables X_1, X_2, X_3, which resulted in their relatively low positions in the final ranking.

The highest share agriculture value added in GDP could be seen in the case of countries in class 2 and 6. In class 2 one can find: Romania, Slovak Republic, Greece and Hungary. In the class 6 there are: Lithuania and Bulgaria. Almost four times higher agriculture value added in GDP in comparison with the countries from Class 3 indicates relatively high share of agriculture in product generation in the economies of these countries. In class 4 one can find: Poland, Portugal and Spain. These countries are characterized by an average level of all 6 variables, which is reflected in the rankings.

Conclusions

In recent decades, significant reforms of the CAP and the enlargement of the EU have amplified research interest in studying the distinct differences in the performance of the agricultural sector in the EU countries. In addition to standard market self-regulation, the regulation of the industry by means of the CAP has played an important role in this sector. The CAP was created to regulate and support European agriculture. Inter alia, the aim of the CAP is to assist the development of agriculture of the EU member states and to mitigate differences in its performance (European Council, 2001).

In this contexts, the aim of the article was to study disparity in the agriculture and food industry sectors' performance in the EU countries during the period 2010 to 2013. Two methodological approaches: Taxonomic Measure of Development proposed by Hellwig and Ward's method were used. The results of both methods are consistent. They confirm the existence of significant disparity in the performance of agricultural sector between the old and new member states that joined the UE after the year 2004. Old EU member states Netherland, Belgium, France, Denmark, and Germany with hilly intensive agriculture rank the top five position. From new member states only Estonia and Latvia are among the top ten positions, remaining accessing countries are listed at last rank positions.

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