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CLUSTER ANALYSIS OF BEEF PRODUCTION DISTRIBUTION IN EUROPE

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ABSTRACT

Fragmentation and poor connection within the beef production industry affects its positive contribution to the economy, land management, and development of rural areas. Despite the third place in world beef production European countries have achieved one of the best results in environmental management of cattle breeding worldwide. On the other side there is a huge variability of beef and veal production on national and regional level, reflecting the varied geographical, economic and social requirements of different European regions. Even in case of moderate beef consumption (16 kg per capita per year) in the European Union, meat as the source of proteins of animal origin is connected to higher value added, higher employment, profit and incomes in agriculture comparing to crop production. On the other side it also requires higher investments and represents a greater risk. Different levels of agrarian subsidies and the efficiency of their use exacerbate the differences in the production of beef and veal in the countries of the European Union. In submitted paper we investigated beef production distribution similarity of selected countries in Europe. Quantitative approach was applied using cluster analysis in accordance with the Ward's minimum variance method with previous computation of similarity of the territories through the Euclidean distance. Three clusters representing the beef production similarity among the explored countries were visualised by dendrograms within observed steps in the year 2008 and the year 2017. Order of similarity and dissimilarity in beef production according to the Euclidean distance values of all the possible pairs of the districts from the whole data set in observed countries was processed for examined period of time. Finally, the heat maps were constructed to demonstrate the similaritity between each pair of the comprised countries. Obtained results could serve as a valuable resource for meat producers to understand the time dynamics impact and differences in level of beef production in European countries.

Keywords: bovine; meat production; cluster analysis; Euclidean distance

INTRODUCTION

Production of food of animal origin is an important part of securing nutrition of the growing population. The impacts of volatility of agricultural production alleviate the food trade internationalization. New societal challenges such as population growth, urbanization, climate changes, innovations, changes in the demographic structure of the population bring about changes that have a significant impact on the agricultural economy and rural life **(Paraschiv, 2016; Kowal et al., 2016; Mura and Mazák, 2018)**.

The World Summit on Food Security named the four pillars of food security: availability, access, utilization and stability **(World Summit on Food Security, 2009)**. The latest research on characteristics of signs of increasing food insecurity showed the urgent need for considerable additional work to ensure we "leave no one behind" on the road towards achieving the goals on food security and nutrition **(Food and Agriculture Organization of the United Nations et al., 2018)**. In response to these facts in the member states of the European Union national and European policies and strategies were developed, in addition to the common agricultural policy and the Europe 2020 Strategy, in particular, the medium and long-term strategy 2020–2030 for agri-food sector.

Products of animal origin are no longer considered only in terms of quality (ex. flavour) but also safety, nutritive value, sustainability of production methods and animal welfare standards are becoming increasingly important. In these conditions, cluster analysis is a very useful complex statistical method that allows to investigate consumers' behaviour more precisely then using traditional methods **(Gábor et al., 2010; Tekień et al., 2018)**.

The demand for beef as a protein source is increasing worldwide, but in the European Union, consumption of beef declined since 25 kg in 1985 to nowadays 16 kg equivalent **(Hocquette et al., 2018)**. The sustainability of beef production has different meanings in the various geographical and socio-economic regions of the world. Natural resources including land mass and uses, rainfall

and access to livestock feed, and the robustness of the economy are major determinants of the perception of beef sustainability **(Smith et al., 2018; Mura and Gasparikova, 2010)**. **C**ountry of origin as regional aspect of animal production, denoted by labelling, become more important lately **(Sepulveda et al., 2011)**. Also, the other credence attributes associated with cattle production – production system, feeding, animal welfare, slaughtering, traceability, among others – have acquired importance for meat products in developed countries, representing information that must be included on label **(Schnettler et al., 2009)**.

Environmental impact of beef production

Various approaches have been carried out to extrapolate environmental assesments of animal production **(Avadi et al., 2016)**. Increasing volume of animal production due to growing food demand and needs is connected to serious environmental problems. Cattle emits the highest, about 65% of the livestock production emissions of greenhouse gases **(Fiore et al., 2018)**. The emission intensity of beef from specialised beef herds is almost fourfold that produced from dairy herds. On the other side, in Europe, about 80 % of the beef is produced from dairy animals, surplus calves and culled cows, resulting in lower emission intensities, which are the most efficient and least polluting in the world **(Gerber et al., 2013; Hocquette et al., 2018)**. The diverse nature of beef production was captured by establishing a farm typology using principal component analysis and cluster analysis. The typology not only provided a strategy by which the beef cattle industry could be characterised, but also improved understanding of the diversity of farm management practices to help develop policies and beneficial management practices **(Alemu et al., 2016; Jasińska-Biliczak and Sitkowska, 2014)**.

Beef origin and consumer preferences

Beef consumption is generally associated with developed countries and with high levels of total meat and poultry consumption **(Cottle and Kahn, 2014)**. Understanding consumers segment preferences towards food products of animal origin plays crucial role in food research **(Tekień et al., 2018)**. Meat consumption diversification for many reasons is influenced by cultural preferences or economic status of the households. This phenomenon is also indicated by the magnitude of positive cross price elasticity between beef and mutton, beef and poultry meat, and between poultry meat and fish. Therefore, every effort to push higher consumption of one meat type, will reduce the participation rate of others **(Soedjana, 2013)**. Consumers did not prefer the same type of meat within the same country and it is possible that there are individual preferences that could lead to the concept of market segmentation being based on taste preferences. It would appear that Uruguayan beef would be very acceptable in Germany and to a lesser extent in Britain and Spain **(Oliver et al., 2006)**. Results of the Spanish study of consumers' preferences is of great interest in the beef sector, where the bovine spongiform encephalopathy crisis generated deep changes in the basic conditions of demand for meat and in the behaviour of consumers. Results showed that the origin of the product is the most important attribute for the choice of beef, followed by quality labelling, production system and price **(Mesias et al., 2005)**. Market research results confirmed connection of certain consumer segments preference of beef consumption to the brand and area of origin. Branded beef produced under high production standards enjoys a higher level of trust and consumers are willing to pay comparatively higher prices for such products **(Hochuli et al., 2018)**. The most important factor explaining the differences among consumer responses relates to consumers' perceptions of the importance of meat attributes related to production practices – for instance use of antibiotics, hormones and environmentally friendly grazing. Interestingly, the consumer segments that are willing to pay a significantly higher premium for natural, local beef are motivated by different aspects of the meat and its intrinsic production attributes **(Thilmany et al., 2006)**.

Beef production systems diversity

Comparison of the beef production systems to establish the main technical, socio-economic and productive aspects of the beef farms showed their differences in term of orientation market type, intensification level, dimensionality and economic performance **(Perea et al., 2014)**. The intensification process of the livestock sector has been characterised in recent decades by increasing output of product per hectare, increasing stocking rate, including more concentrated feed in the diet, and improving the genetic merit of the breeds. Clusters of farms characterised by different levels of production intensity showed similar environmental performances on product basis, despite important differences in terms of intensification level, management, and structural characteristics. Considering the environmental burden on a local perspective, the impacts per hectare were positively associated with the intensification level **(Bava et al., 2014)**. Clustering of livestock system based on the production intensity showed that the intensive systems had larger herds, modern structures and equipment, and were strongly production oriented, whereas the extensive systems had smaller herds and productivity, with often traditional or obsolete structures and equipment, but showed a tendency to diversify production or mixed farming of different livestock categories eventually. Livestock systems differ not only in production practices but also in the ability to maintain landscape, which is generally higher in the extensive or even marginal systems **(Sturaro et al., 2009; Kordoš, 2015; Stasiak-Betlejewska, 2015)**.

Beef production in Europe

Heterogeneity of livestock numbers distribution and study of dynamics of its change were found fundamental to the identification of drivers that shaped the various intensification trajectories and led to these different states, as well as to the prediction of future changes **(Domingues et al., 2018)**. Investigation of production volatility by species showed the highest variation coefficient for the production of live weight meat in beef, followed by poultry meat and mutton and goat meat **(Grodea, 2016)**.

The European Union is the world's third largest producer of beef after the United States of America and Brazil with almost 8.0 million tons of carcasses in 2018 **(Hocquette et al., 2018)**.

The number of cattle in the Slovak Republic reached 446.1 thousand in 2016, of which the number of cows was 194.2 thousand heads **(Ministrstvo pôdohospodártsva a rozvoja vidieka Slovenskej republiky, 2017)**. In 2017, 44.063 tonnes of carcass weight of beef cattle were sold in the Slovak Republic as well as 1.316 tonnes of calves. At the Slovak slaughterhouses, 29.3 thousand cattle heads were slaughtered with a carcass weight of 7.8 thousand tons. Domestic consumption of beef is estimated to be 26.400 tonnes in 2017, which is 4.9 kg per capita per year **(Gálik, 2018)**. Due to regional differences in terms of climate and pasture availability, and also in terms of livestock practices and fattening farm characteristics, the productivity and incomes of beef producers vary widely across European countries and regions, being regularly among the lowest of the agricultural systems **(Smith et al., 2018)**. The heterogeneity of the European Union cattle sector at the regional level is substantial. Pronounced differences exist between regions in western and eastern, as well as between regions in northern and southern European Union member states **(Ihle et al., 2017)**.

Aim of the article was to provide the cluster analysis of beef production within the member countries of the European Union which will allow to understand their similar behaviour, livestock practices, as well as different environmental policies and their future scenarios.

Scientific hypothesis

The fundamental goal of the analysis is to construct a potential platform to be ready to prepare the common directives creating a policy framework aimed at a set of the mutual rules providing a better support in the process of regulation of the appropriate markets where the analysed fragment of the beef production is traded.

MATERIAL AND METHODOLOGY

The methodology selected to carry out the analysis is adapted to the data obtained from the database. Animal production statistics cover three main sub-domains based on three pieces of relevant legislation and related gentlemen's agreements.

Data

The data comes from the database of the Statistical Office of the European Union (Eurostat). It contains the tables from the database "Meat production and foreign trade" marked apro_mt_pann **(Eurostat, 2018a)** and the database "Cattle population" marked apro_mt_lscatl **(Eurostat, 2018b)**.

According to the metadata manual of the Eurostat Animal Production Statistics, bovine animal is domestic animal of the *Bos taurus* species, which covers cattle, and the *Bubalus bubalis* sp., covering water buffalo, respectively domestic Asian water buffalo, including hybrids like *Beefalo* **(Eurostat, 2017)**. This integration is done due to clarification of the implementation of buffaloes and hybrids into this category.

There is to note that census of bovine population is due only once a year for the member states of the European Union where its size is below a one and a half million level when counting heads. A statistics accuracy is determined by the European Commision regulation in a way that the sampling error for the results of each member state of the European Union has not to exceed 1% of the total number of bovine animals in a case of the members whose population is above and equal to one million head and 5% in a case where the population is below one million head with a confidence interval of 68% **(European Commission, 2008)**.

The data source may come out from sample survey or census. Nevertheless, administrative source may represent a basis for obtaining the requested result in order to limit burden on the respondents. This is especially the case for bovine livestock according to the database manual.

The dimensions of the analysis cover a territorial angle of a view an area of the countries whose data is provided by the Eurostat and from a time perspective a time span from 2008 to 2017 is involved. The data is comprised in an annual way, which is the most often provided time interval for this data. Regarding to its characteristics, it is a suitable and common time interval.

An observed set of the area involved in the analysis consists of the following countries: Albania (AL), Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Cyprus (CY), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (GR), Hungary (HU), Iceland (IS), Ireland (IE), Italy (IT), Kosovo (XK), Latvia (LV), Lithuania (LV), Latvia (LT), Luxembourg (LU), Malta (MT), Montenegro (ME), the Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO), Serbia (RS), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), Turkey (TR), United Kingdom (GB). There is only to note minorly that Kosovo uses the temporary code XK until it will be assigned the final code. The mentioned countries are ordered alphabetically according to their colloquial alternative name. They are called by the alternative names in the further text of the paper. These abbreviations are determined by the International Organization for Standardization 3166-1 standard that is part of the the International Organization for Standardization 3166 norm **(International Organization for Standardization, 2013)**. Especially, the two-letter entry of the mentioned standard is applied in the results section of the paper.

There is to note that not all the countries have provided the data for the whole analysed period. Therefore, the mean data are applied to carry out the cluster analysis for a whole time span case.

Methodology

There are several quantitative methods applied in the given analysis. The main approach is the cluster analysis. Firstly, the normalisation of the data is applied too in order to get it to be compared mutually.

Secondly, the similarity of the territories is computed through the Euclidean distance:

$$D(c_1, c_2) = \sqrt{\left(c_{1_x} - c_{2_x}\right)^2 + \left(c_{2_y} - c_{2_y}\right)^2}$$

where the involved variables mean:
- c_1 – the first country;
- c_2 – the second country;
- $D(c_1, c_2)$ – the mutual Euclidean distance of c_1 the country and the c_2 country;
- c_{1_x} – the x coordinate of the c_1 country;
- c_{2_x} – the x coordinate of the c_2 country;
- c_{1_y} – the y coordinate of the c_1 country;
- c_{2_y} – the y coordinate of the c_2 country.

Thirdly, a number of clusters is determined according to the following methods:
- the Ball-Hall index **(Ball and Hall, 1965)**;
- the McClain-Rao index **(McClain and Rao, 1974)**;
- the point-biserial correlation coefficient **(Milligan, 1981)**.

Successively, the cluster analysis is carried out itself. This means a construction of the clusters in accordance with the Ward's minimum variance method.

The final step of the analysis is a creation of the heat maps displaying the similarities of the individual pairs of the explored countries. This graphical output supplements the dendrograms appropriately.

Statistic analysis

The whole analysis is executed in the R statistical environment through the programming language R **(R Core Team, 2018)** using the three packages: *NbClust* **(Charrad et al., 2014; Charrad et al., 2015)**, *shape* **(Soetaert, 2018)** and *gplots* **(Warnes et al., 2016)**.

RESULTS AND DISCUSSION

Firstly, a number of clusters is determined by means of the described methods in the previous chapter. The more detailed information is shown in the Table 1.

According to the selected approaches, a number of clusters representing the beef production similarity among the explored countries is determined to three. The situation looks like as follows at the beginning of the explored time span. The first cluster consists of a majority of the involved countries where Luxembourg, Cyprus, Malta, Bulgaria, Estonia, Slovakia, Hungary, Lithuania, Slovenia, Portugal, Croatia, Greece, Denmark, Sweden, Latvia, Czechia, Finland, Belgium, Austria, Romania, Ireland, and Poland belong. This cluster encompasses the 22 countries. The second cluster is created by the four countries. It involves Spain, United Kingdom, Germany, and Italy. The third cluster consists of only the two countries: France and the Netherlands. The mentioned countries are ordered according their position in the dendrogram.

There are visible some changes in the distribution of the clusters visualising similarity of the analysed beef production situation related to the end of the explored time span in 2017. The biggest first cluster involves 28 countries, where Croatia, Lithuania, Serbia, Latvia, Hungary, Slovenia, Cyprus, Iceland, Malta, Bulgaria, Slovakia, Estonia, Luxembourg, Bosnia and Herzegovina, Montenegro, Albania, Kosovo, Portugal, Greece, Romania, Sweden, Finland, Czechia, Turkey, Belgium, Austria, Denmark, and Switzerland. The second cluster is created only by the sole country, Spain. All the remaining coutries participating in the second cluster before: Germany, United Kingdom, and Italy are assigned to the third cluster in succession. They are followed by Ireland, Poland, France and the Netherlands. Poland and Ireland are only new countries in this cluster, as they are assigned to the osculant tail of the first cluster at the beginning of the explored period in 2008.

The mean situation, as it could be called, is constructed according to the mean Euclidean distances between the individual countries throughout the whole observed period. This illustrates the countries, which are similar in a field of the beef production for the whole observed period. It is partially different than the intiating point and the terminating point of the explored time span. The substantial structure from an angle of view of number of the involved countries is very similar, as the first cluster comprises a big majority of the elaborated entities:

Table 1 The numbers of clusters of the observed countries according to beef production distribution.

Method	Statistic	Statistic value	Number of clusters
Ball-Hall index	barycentre mean dispersion	503.5025	3
McClain-Rao index	denominator	0.0828	3
point-biserial correlation coefficient	correlation	0.8822	3

Table 2 The most similar and the most dissimilar countries according to beef production distribution.

Year	The nearest pair of the countries			The outermost pair of the countries		
	Distance	Country 1	Country 2	Distance	Country 1	Country 2
2008	0.01995	CZ	FI	11.33987	FR	MT
2009	0.01891	EE	LU	11.43255	FR	MT
2010	0.01493	EE	LU	11.67193	BG	ES
2011	0.01522	EE	LU	11.51365	FR	MT
2012	0.00989	EE	SK	11.63335	FR	MT
2013	0.00816	EE	SK	11.60456	FR	MT
2014	0.01077	CY	IS	11.80299	FR	MT
2015	0.00998	LU	SK	12.52704	FR	MT
2016	0.00944	LU	SK	11.41347	FR	TR
2017	0.01026	BG	SK	12.52704	FR	SK

Sweden, Czechia, Finland, Iceland, Malta, Slovakia, Estonia, Luxembourg, Montenegro, Bulgaria, Cyprus, Albania, Bosnia and Herzegovina, Lithuania, Hungary, Slovenia, Latvia, Serbia, Denmark, Portugal, Kosovo, Croatia, Greece, Romania, Ireland, Poland, Austria, Turkey, Belgium, and Switzerland. The second cluster consists of only the two countries and it has the same content as the third cluster from the beginning of the explored period in 2008: its members are France and the Netherlands. Finally, the third cluster encompasses the four countries, which are the same countries that are included in the second cluster at the beginning of the observed time span: these are Spain, Italy, Germany, and United Kingdom.

It is an interesting alteration of the intitating situation, because this expresses a considerable move of these four

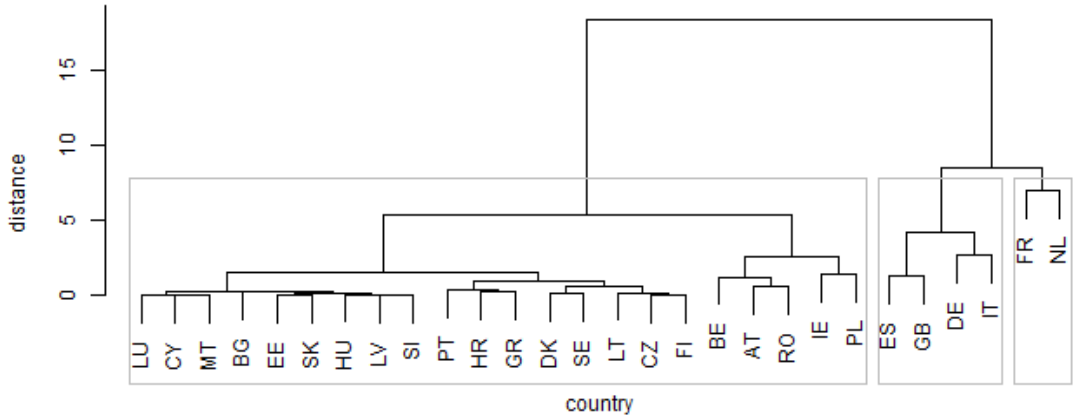

Figure 1 The dendrogram of the beef production distribution similarity according to the explored countries for the year 2008.

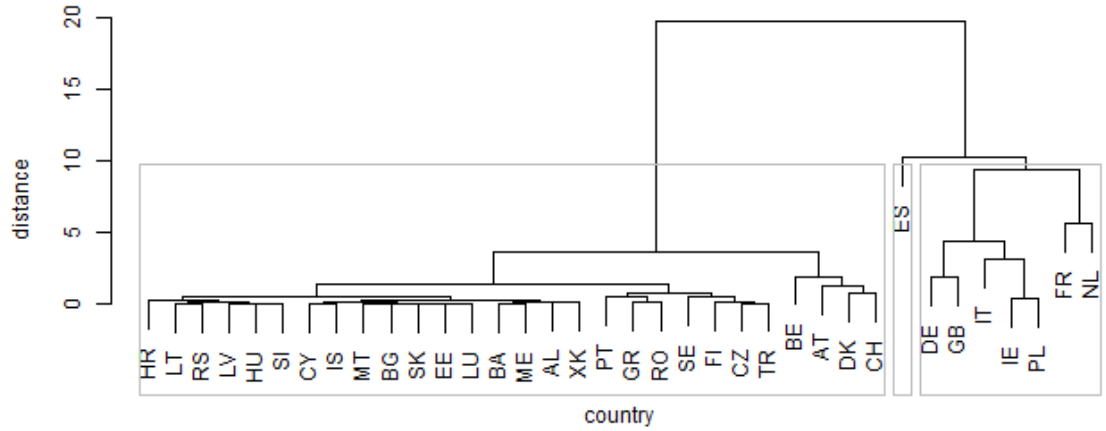

Figure 2 The dendrogram of the beef production distribution similarity according to the explored countries for the year 2017.

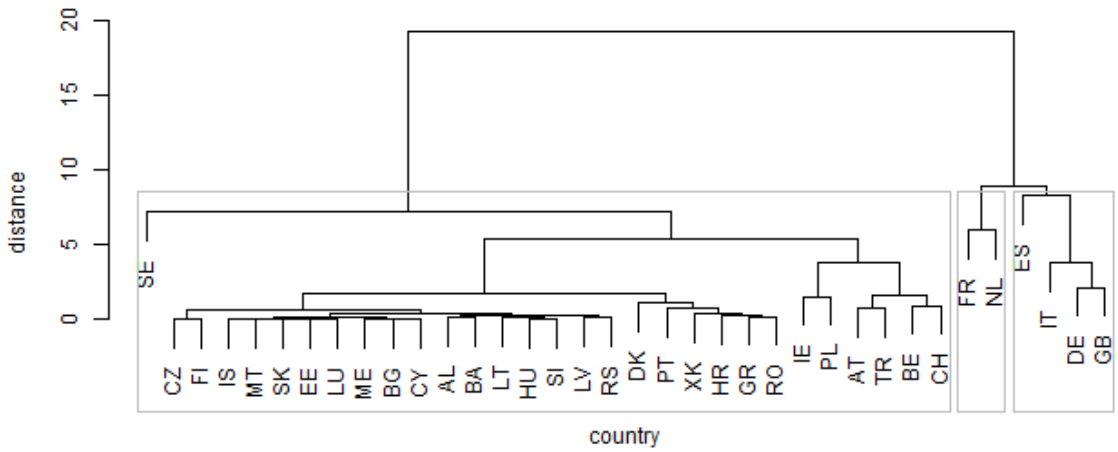

Figure 3 The dendrogram of the beef production distribution similarity according to the explored countries for the whole observed period.

countries further from a remaining majority represented by the first cluster.

Table 2 shows the most extreme similarities according to the Euclidean distance values of all the possible pairs of the districts from the whole data set. The displayed values are rounded to five decimal places. As it is seen, the most similar pairs are created by the eight countries, which Bulgaria, Cyprus, Czechia, Estonia, Finland, Iceland, Luxembourg, and Slovakia belong among.

The most mentioned countries are Estonia, Luxembourg and Slovakia, all three entities five times. Each one of the remaining countries is represented only once. The most similar pair, the nearest one of the whole explored time span is created by Estonia and Slovakia in 2008 with the Euclidean distance value of 0.00816.

On the other hand, the most dissimilar pairs of the countries are represented the six various countries throughout the whole analysed time span, which Bulgaria, Estonia, France, Malta, Slovakia, and Turkey belong among. France is set all, but one years and Malta is located here seven times. The remaining four countries are represented only once. The absolutely biggest disparity during the whole explored period at a level of 12.52704 is found twice: between France and Malta in 2015 and between France and Slovakia in 2017. There is to note for curiosity, Slovakia appears in the both sides: several times it creates the nearest pair and once it creates the outermost pair. Such a result can be expectable because Malta and Slovakia dispose an absolutely different composition of the cattle livestock holdings.

The following heat maps demonstrate the similaritity between each pair of the comprised countries. Each cell is assigned the particular shade of gray: the darker colour is placed, the more distant pair of the countries there is. It means such countries have more similar situation in beef production. The first heat map shows a situation at the beginning of the explored period in 2008.

As it can be seen from the previous heat map on Figure 4, there is clearly visible that there are the three countries which stand out among the other countries. This triplet consists of France with the average mutual distance to all the other countries at a level of 9.84472, Italy with a distance of 6.46702, and the Netherlands with a distance of 6.21732. Successively, the United Kingdom with a distance of 4.88268 and Spain with a distance of 4.09161 are visibly more distant from the remaining group of the involved countries.

The second heat map visualises a situation at the end of the explored period in 2017.

Figure 5 demonstrates the final situation in the analysed field. France with the average mutual distance to all the remaining countries in the data set at a level of 9.42508 is the outermost entity. It is followed by Spain with a distance of 8.85159, the Netherlands with a distance of 7.27699, Germany with a distance of 6.34874, the United Kingdom with a distance of 5.22425, Italy with a distance of 5.05540, Poland with a distance of 4.61316 and finally, Ireland with a distance of 3.82692.

The third heat map visualises a situation according to the mean values of the observed countries for the whole explored period from 2008 to 2017.

The final heat map on Figure 6 demonstrates the average situation of the whole analysed time span. The outermost

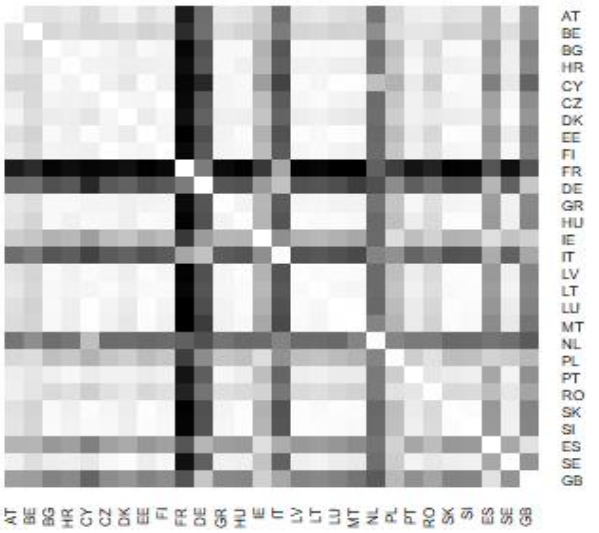

Figure 4 The heat map of the beef production similarity according to the explored countries for the year 2008.

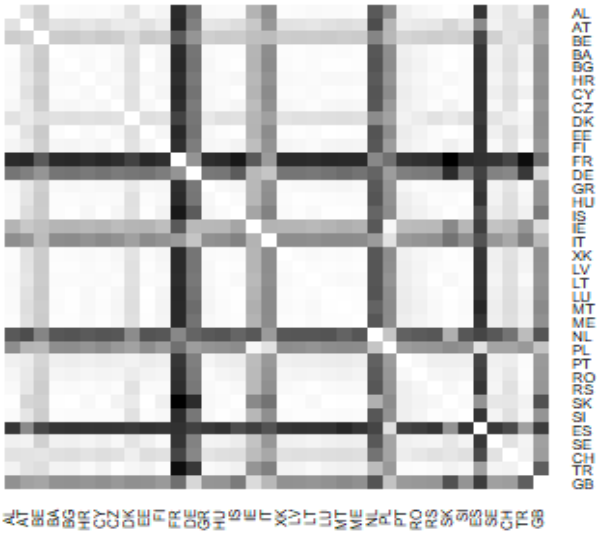

Figure 5 The heat map of the beef production similarity according to the explored countries for the year 2017.

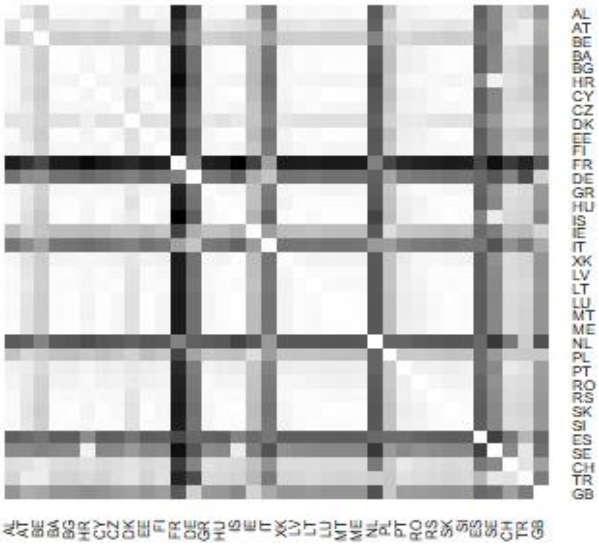

Figure 6 The heat map of the beef production similarity according to the explored countries for the whole observed period.

country is France again. It lies the most distantly: at a level of 10.03562 Euclidean units. It is followed by the Netherlands with a value of 7.58086, Spain with a value of 7.27290, Germany with a value of 6.30685, Italy with a value of 6.06541 and, finally the United Kingdom with a value of 5.00537.

Obtained results of the mean situation of clustering, namely the third cluster containing Germany, the United Kingdom, Italy and Spain, showed the same order of beef production as the results of **Hocquette et al. (2018)**. The mean distance of the second cluster, represented in our results by France and the Netherlands are much higher in their results in both total cattle numbers in 2014 and beef production in 2016. Also, the results of **Ihle et al. (2017)** confirm that Germany, France, the United Kingdom and Italy account for half of the gross production value of the EU cattle sector. They also stated that the EU cattle herd is concentrated in and around the Benelux, the Alps, eastern Poland, north-western France and Ireland, and confirm the substantial regional differences of the EU cattle sector in western and eastern, as well as northern and southern member states. **Mauracher and Valentini (2006)** in their work clustered Europe into four regions based on level of meat consumption with high consuming cluster containing Austria, Finland, France, Ireland, Switzerland and the United Kingdom, and the low income and low meat consumption cluster containing Albania, Bosnia and Herzegovina, Cratia, Moldova, Romania and the Former Yugoslav Republic of Macedonia.

The results of **Smith et al. (2018)** focused to future prospect of global beef production mentioned unprecedented challenges of European beef industry related to animal welfare, environmental impact, origin and authenticity of beef, nutritional benefits, and consistency of eating quality.

CONCLUSION

Evolution of food consumption and associated meat production in European countries has been analysed with focus to general picture as well as on the level of specific regions. Significant regional differences within the European Union member countries reflect the geographical, economic and social requierements of different European regions. Provided cluster analysis showed grouping of countries based on the similarity of the territories through the Euclidean distance and its time dynamics within observed periods 2008 and 2017. Created heat maps displayed the similarities of the individual pairs of the surveyed countries. Obtained results can serve as background for preparation of common directives of policy framework of beef production, as well as to understand the future changes within the beef production industry.

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