www.jard.edu.pl http://dx.doi.org/10.17306/J.JARD.2018.00436

Journal of Agribusiness and Rural Development

pISSN 1899-5241
eISSN 1899-5772

4(50) 2018, 445–454
Accepted for print: 12.10.2018

ECONOMIC FACTORS UNDERPINNING THE STRUCTURAL GENOTYPES OF AGRICULTURE DEVELOPMENT IN THE EUROPEAN UNION AFTER 2004

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Abstract. The purpose of this study was to identify the similarities and differences between EU-27 countries in production structures of the agricultural sector. The investigation focused on the concentration of productive inputs as well as on the specialization and orientation of production processes because of the relationship these characteristics have with production efficiency. The indices used in the Ward's clustering method were estimated based on data from the 2005–2013 Farm Structure Survey. The Mann–Whitney U test was used to determine the statistical significance of differences between the clusters. Four structural genotypes of agriculture were identified. While the EU-12 (genotype IV) and EU-15 (genotypes II and III) differ considerably in productive inputs and production concentration, the differences in prevailing production patterns are less pronounced. EU-15 countries differ mainly in the specialization level, and are similar in terms of production concentration. The genotypes identified do not coincide strictly with the typical EU-12/EU-15 aggregates. This is because Southern European countries (Spain, Portugal, Greece and Italy), although members of the EU-15, are closer to the structures characteristic of EU-12. Conversely, although the Czech Republic and Slovakia joined the EU only in 2004, they have the highest concentration rates.

Keywords: agricultural production structures, structural genotypes, resource concentration, production specialization, comparative analysis

INTRODUCTION

In the Communication "The Future of Food and Farming" published on November 29, 2017, the European Commission (2017, p. 3) notes that within the Common Agricultural Policy (CAP) "the Union should set the basic policy parameters, while Member States should bear greater responsibility and be more accountable as to how they meet the objectives and achieve agreed targets." This is a prerequisite for sector-specific research. In the CAP after 2020, it will probably be crucial for the agricultural sector of individual countries to be characterized by specific parameters which will provide a framework for evaluating the effectiveness of measures financed under the CAP. This study is consistent with the spirit of these changes. Although similar research has already been undertaken (Czyżewski and Henisz-Matuszczak, 2004; Pawlak and Poczta, 2010; Majchrzak, 2015; AKI, 2016; Bożek, 2016; Popescu et al., 2016), it offers a perspective which leaves room for further analysis consisting in a synthetic presentation of structural conditions (genotypes[1]) for the continued

[1] This term is a reference to the concept of functional genotypes of cities presented in a paper by Gwosdz (2013). Originally, they are defined as a set of functions with a decisive impact on the creation of a city or on the development and location pattern of cities (Krzysztofik, 2012, after: ibid, p. 22). In the context of

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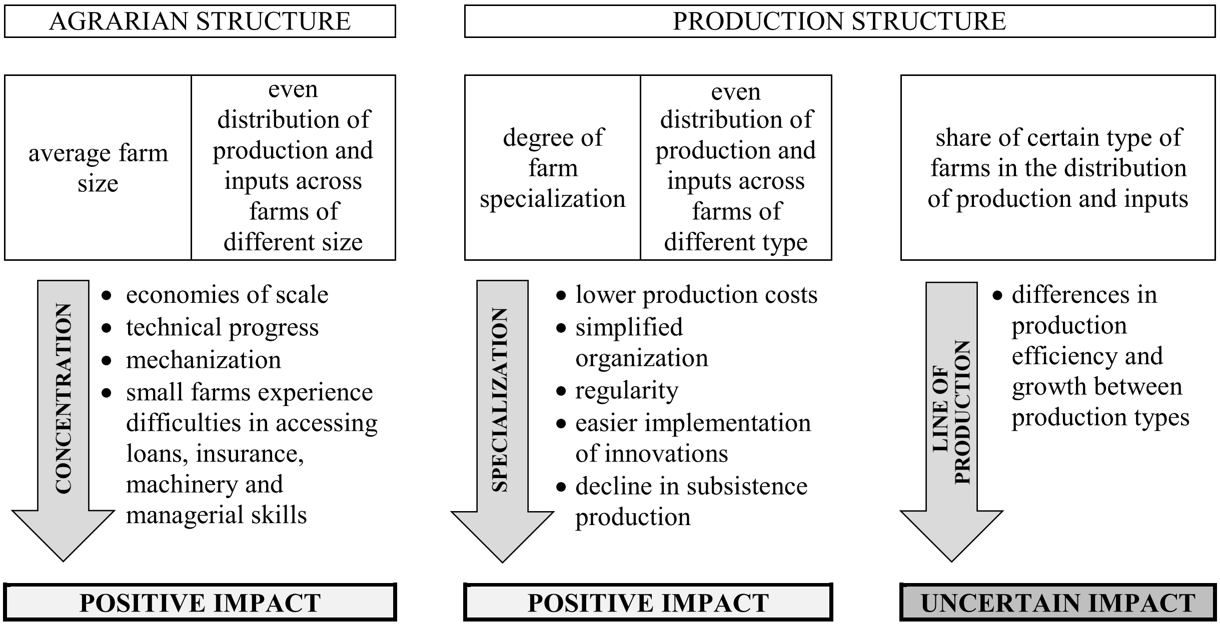


Fig. 1. Impact of structures and structural changes on the efficiency of agriculture
Source: own elaboration based on literature review.

development of agriculture in EU countries (assessed in terms of growth in production productivity). Therefore, the purpose of this study is to identify structural genotypes in EU countries[2] based on structural characteristics, based on selected structural characteristics, related to agricultural productivity. The results of this research may provide valuable insights for the future diversification of CAP instruments so that they are tailored to specific needs of countries clustered in a specific genotype.

RELATIONSHIPS BETWEEN PRODUCTION STRUCTURE AND EFFICIENCY IN AGRICULTURE

Production structures are an extremely broad concept, which makes it difficult to adopt a comprehensive approach. Because of the research agenda, it was decided to narrow the scope of the analysis to the dimensions of production structures which are theoretically proven to have an impact on the economic efficiency of agriculture. This approach is summarized in Figure 1.

As Chavas points out (2001, p. 267), the question of the relationship between farm size and production efficiency is at the heart of the debate on the structure of agriculture. Arguments for the existence of an inverse relationship between farm size and farm productivity are often cited in the literature. This means cases where land productivity decreases with an increase in farm size. One possible explanation for the above is that family members (mainly employed in smaller farms) are more diligent in their work than regular employees (Feder, 1985). According to most empirical studies, the thesis of inverse relationship is only true for developing countries (Lipton, 2010, p. 1399). In developed countries, this effect fades because of production mechanization and technological progress. In poorer countries, low capital expenditure and poor mechanization make it possible for small farms to gain an advantage as a result of greater work diligence. Meanwhile, in developed countries where labor is already largely substituted by capital, small farms may find it difficult to access loans,

agricultural research, it means a structural genotype that can be considered as a set of structural features determining the agricultural sector's functions which, in turn, determine its development.

[2] The authors are aware of the heterogeneity of EU countries, and therefore the average values used in this study are not representative for all of the country's regions. However, considering the "national" model of CAP evaluation which is likely to be put in place after 2020, the authors believe the generalization to be justified.

insurance or other specific inputs (machinery, animals or managerial skills). At the same time, some advanced technological solutions (GMOs, precision farming) require an appropriate scale of production in order to remain cost-effective (Deininger et al., 2013, p. 5). In view of the above, Zegar (2009, p. 9) even states that improvements in the agrarian structure (higher concentration) are a sine qua non condition for increasing the economic, productive and social efficiency of agriculture. These considerations are the reason why this study uses structural genotypes of agriculture as variables describing the agrarian structure or, more broadly, the average size of farms. This approach was extended by Wołek (2009) who noted that the key aspect is the concentration of land rather than the concentration of production which can be achieved by other means (co-operation, intensified use of other productive inputs). Moreover, concentration may be accompanied by polarization of the agrarian structure which remains unnoticed if the analysis focuses solely on the average area of farms. This opens the door for further paths of structural analysis of agriculture which take the issue of land distribution into account. In this case, too, the "inverse relationship" is observed, i.e. land productivity decreases along with an increase in concentration. Vollrath provides a comprehensive overview of research on this topic (2007, p. 203–204). The author also proves the existence of this relationship based on research into a diverse group of 117 countries.

Reducing the structure of agriculture to the agrarian structure alone can therefore be considered an oversimplification. Improvements in the efficiency of farming management may also be driven by specialization. Although linked to the concentration processes discussed above, it "rather expresses the production line of the holding, defined by the main commodity product, whereas concentration determines the production volume of that commodity" (Zegar, 2009, p. 9). With the development of agricultural markets, farms can move from diversified subsistence production to commodity management. This allows farmers to focus their skills on certain selected projects while having grater control over production and efficiency. Also, it facilitates marketing activities and contributes to the reduction of transaction costs. As a result, farmers (and often also regions specializing in a given line of production), start leveraging their comparative advantages to highlight local production characteristics (Chavas, 2001, p. 275). Just as land productivity was crucial for the impact of concentration, labor productivity is crucial for specialization. Wilkin (2013, p. 51) describes the "development trap" the owners of small farms in Poland are caught into. On the one hand, institutional conditions have been created for them in the form of certain privileges (direct payments, tax and social privileges). But on the other hand, land and poorly productive human resources remain unchanged. Many of these farms are unable or unwilling to expand and modernize. All this leads to an "equilibrium in poverty" which has a deteriorating effect on the sector's labor productivity. From the microeconomic perspective, the prerequisites for specialization include the willingness to: (1) reduce production costs, increase the efficiency of agricultural marketing, save labor, and increase labor productivity; (2) simplify the production organization; (3) improve product quality and standardization to facilitate subsequent marketing; (4) ensure the regularity of transactions; (5) introduce efficient but expensive machinery which makes it necessary to standardize production processes; (6) make progress and address the associated need for knowledge, which is minimized if specialization efforts are made; (7) improve the skills of production staff (Czyżewski and Smędzik-Ambroży, 2013, p. 1). 26). Note that non-specialized holdings generally consume a significant part of their production by themselves. Because that production does not enter the market and its value is not reported, it has the nature of an self-consumption. Note that the above is true for a large percentage of farms, and therefore the overall output of the agricultural sector is underestimated, as reflected in low resource productivity figures. Having in mind that subsistence farms usually have relatively small land resources and relatively large amounts of labor, the labor productivity ratio is the most underestimated one (Gollin et al., 2004).

The third dimension of the agricultural structure to be considered is the orientation of the production structure. It can be crucial to identify the dominating products in the national agriculture sector and the production type which uses the relatively largest amounts of resources. The questions to be asked when considering production specialization are whether any line of production is of particular importance, and whether the farms focus on one or many types of production (the choice between economies of scale and economies of scope). When analyzing the production structure, the impact of specialization on a specific line of production has to be considered.

Table 1. Structural indicators used in the research

Feature	Indicator	ID	Eurostat code
Concentration	average area of the holding (UAA)	AVG_UAA	ef_kvfta
	average economic size of the holding (SO)	AVG_SO	ef_kvfta
	average labor inputs (AWU)	AVG_AWU	ef_kvfta
	average livestock numbers in livestock holdings (FT45, 46, 47, 48, 51, 52, 53, 73, 74, 83, 84) (LSU)	AVG_LSU	ef_kvfta
	distribution of land between holdings of different economic size (UAA/SO)	UAA_SO	ef_kvftecs
	distribution of production between holdings of different economic size (SO/SO)	SO_SO	ef_kvftecs
	distribution of labor between holdings of different economic size (AWU/SO)	AWU_SO	ef_kvftecs
	distribution of livestock between livestock holdings of different economic size (LSU/SO)	LSU_SO	ef_kvftecs
Specialization	share of households where more than 50% of production is used for self-consumption	SELF_CONS	ef_kvecsleg
	share of mixed production holdings in the total production value (SO)	MIXED	ef_kvftecs
	distribution of land between holdings of different types (UAA)	UAA_TYPE	ef_kvftecs
	distribution of labor between holdings of different types (AWU)	AWU_TYPE	ef_kvftecs
	distribution of livestock between holdings of different types (LSU)	LSU_TYPE	ef_kvftecs
	absolute specialization: distribution of production between farms of different type (SO)	ABS_SPEC	ef_kvftecs
	relative specialization: distribution of production between holdings of different type (SO)	REL_SPEC	ef_kvftecs
Production line	share of the value of animal production (ANIMAL OUTPUT) in the total value of agricultural production (AGRICULTURAL GOODS OUTPUT) at constant 2005 basic prices	ANIMAL	aact_eaa03

Source: own elaboration based on Eurostat data.

Focus may be placed on the impact the share in resource consumption or in production value has on the sector's efficiency. Economic growth may be driven by the relocation of resources to higher productivity industries (Kuznets, 1979). Therefore, in a situation where any of the lines of agricultural production consistently demonstrates higher levels of productivity, its share in resource use and in the total production value may prove to be an important determinant of the overall efficiency of the agricultural sector. In addition, some links exist between the size and line of production. Smaller farms tend to specialize in more intensive production types (e.g. horticulture, permanent crops) while large farms tend to rely on more extensive production methods (e.g. field crops) (AKI, 2016, p. 120). The above suggests that the share of a specific type of production may have an impact on overall production efficiency, but only if there is a line of production with a significantly higher productivity than the others.

MATERIAL AND METHODS

The best source of data on the structure of agriculture in the European Union is the Farm Structure Survey (FSS). A detailed description of the relevant methodology can be found in Eurostat online resources (2017). Information on the limitations of this data can be found in a study by the Hungarian institute AKI (2016, p. 92–93). Although the survey has been running since 1966, EU-12 data has been available since 2005 and is based on 10-year censuses and mid-term surveys conducted twice between censuses. This study will rely on research carried out for the 2005, 2007, 2010 and 2013 reference periods which offer good comparability between countries and slightly less comparability over time. Based on the theoretical review, and having in mind the limitations in data availability, a set of agricultural structure indicators, as detailed in Table 1, was defined for this study. Except for the indicator of the line of production, all of them were estimated based on FSS data. The indicator of the line of production was based on the Economic Accounts for Agriculture (EAA). The reason for choosing EAA is that the total value of livestock production could not be determined based on FSS because it was partly carried out with mixed holdings. The decision was made to use the economic size of farms as the ordinal variable, because ordering the farms by area could give preference to field crop production.

The Hirschman-Herfindahl index was used to analyze the specialization in absolute terms; it illustrates the degree of dominance of the most important production types over other ones (Palan, 2010, p. 15). The Krugman index was used to analyze the specialization in relative terms. It shows how much does the production structure of a given country differ from the EU average (Palan, 2010, p. 22). The concentration was analyzed with a standard concentration index which is interpreted similarly to the widely used Gini index but also describes the variation in the distribution of a given characteristic among units ordered by other characteristics (O'Donnell et al., 2016, p. 3). The values of all indicators were scaled up so as to range from 0 to 1 and to increase as the degree of specialization or concentration increases.

At the next stage of the study, the Ward's clustering method was used. It uses the analysis of variance to estimate the distance between clusters, and its objective is to minimize the sum of squared deviations inside the clusters. At each stage, of all the possible pairs of clusters, the one which results in minimum variation within the cluster is selected. The Error Sum of Squares (ESS) measures the difference between this variation and the average value for the cluster. The cut-off level, i.e. the distance (link length) at which the dendrogram was cut to produce groups, was determined in accordance with the Mojena rule as the average link length plus 5/4 of standard deviation (Stanisz, 2007, p. 122). The distance between the objects in multidimensional space was determined with the use of Euclidean metrics, and the values of the indicators from the 4 study periods were averaged and standardized. The quality of clustering results was verified using the cophenetic correlation coefficient[3] ($r_{kof.}$) and the STandardized Residual Sum of Squares (STRESS) (Machowska-Szewczyk and Sompolska-Rzechuła, 2012). The non-parametric Mann–Whitney U test was used to determine the statistical significance of differences between clusters because cluster variances were previously found to be unequal based on the Levene's and Brown–Forsythe tests. This analytical approach was detailed in a study by Czyżewski and Smędzik-Ambroży (2017).

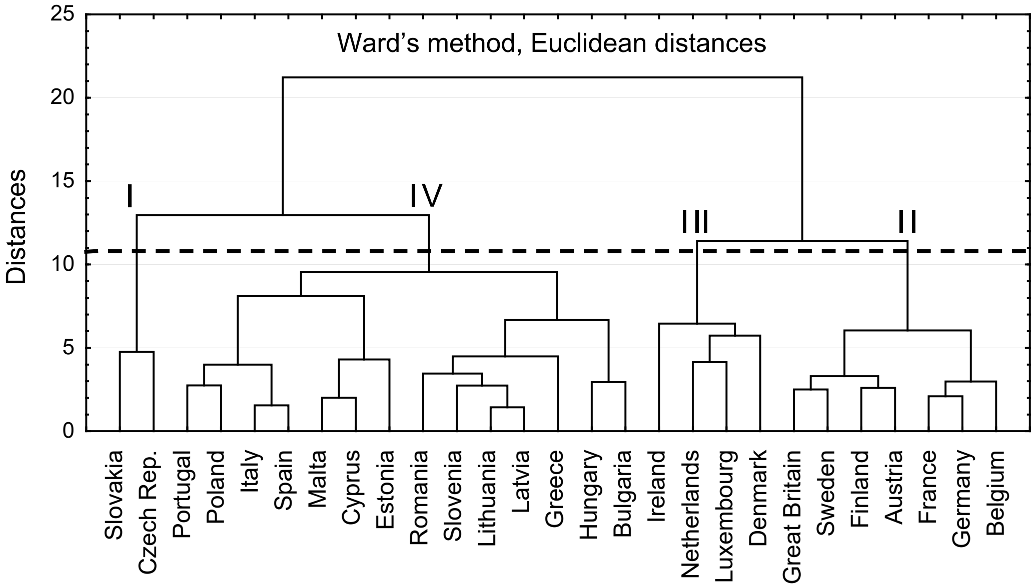
RESULTS

The results of clustering of mean values for variables recorded in the 2005–2013 period are shown in the dendrogram (Fig. 2). The relatively high value of the cophenetic correlation and the low level of STRESS indicate that the dendrogram matches well the Euclidean distances. At the selected cut-off level (10.8), the analysis allowed to identify 4 structural genotypes of countries.

Genotype I is the most homogenous whereas genotype IV is the most heterogeneous and the largest cluster. The smallest cluster (genotype I) was composed of 2 countries: the Czech Republic and Slovakia. Note also that if the cut-off level was slightly higher (around 13), the population would only be divided into two genotypes with a composition similar to that of the EU-12 (genotypes I and II) and EU-15 (genotypes III and IV). The only differences would result from the allocation of South-Eastern European countries (Portugal, Spain, Italy and Greece) to the EU-12.

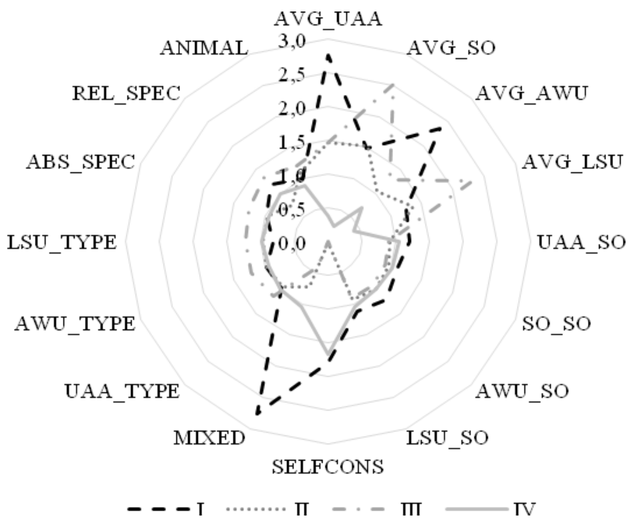
Figure 3 shows the distinctive features of individual clusters. Production concentration is the key aspect which makes genotype I stand out from other groups. In the Czech Republic and Slovakia, farms are 2.7 times larger than the EU average and therefore also employ more labor. However, these countries no longer stand out in terms of average standard output and average livestock numbers. Still, their concentration ratios are the highest, in terms of both productive inputs and output itself, although the Czech Republic and Slovakia

[3] This value is obtained by comparing the Euclidean distance matrix with that of the links resulting from the clustering procedure.



$r_{kof.} = 0.61$, $STRESS = 1.99$

Fig. 2. EU-27 countries clustered by agricultural structure; 2005–2013 average figures
Source: own elaboration based on Eurostat data.



1 means the EU-27 average level
Genotypes: I: Slovakia, Czech Rep.; II: UK, Sweden, Finland, Austria, France, Germany, Belgium; III: Ireland, Netherlands, Luxembourg, Denmark; IV: Portugal, Poland, Italy, Spain, Malta, Cyprus, Estonia, Romania, Slovenia, Lithuania, Latvia, Greece, Hungary, Bulgaria
Features: AVG_UAA: average utilized agricultural area; AVG_SO: average standard output; AVG_AWU: average employment; AVG_LSU: average livestock numbers; UAA_SO: land distribution; SO_SO: standard output distribution; AWU_SO: labor distribution; LSU_SO: livestock distribution; SELFCONS: share of subsistence farms; MIXED: share of mixed farms; UAA_TYPE: land distribution by production type; AWU_TYPE: labor distribution by production type; LSU_TYPE: livestock distribution by production type; ABS_SPEC: absolute specialization; REL_SPEC: relative specialization; ANIMAL: share of animal production

Fig. 3. Diversification of agricultural structures in EU-27; 2005–2013 average figures
Source: own elaboration based on Eurostat data.

do not stand out as much as in the case of average values. However, it should be borne in mind that the overall variation in these variables is smaller. In terms of production specialization, the Czech Republic and Slovakia stand out particularly because mixed farming is commonly practiced. The share of mixed farms in the total number of agricultural holdings is 2.76 times higher than the EU-27 average; as regards the share of animal production, genotype I countries do not differ from the general average. An outstanding feature of genotype

II countries is their production specialization. In these countries, self-consumption of farm output is a marginal phenomenon; also, mixed production is less common among farmers. This picture is seemingly contradicted by the indicator of relative specialization which is the lowest across all clusters. However, this only means that production lines typical of the EU-27 were more common in these countries than anywhere else because this group also includes the EU's main suppliers of agricultural products (France, Germany, United Kingdom) which largely impact the production structure of the EU. Production concentration in genotype II is high, especially in terms of average area of UAA per holding, standard output and livestock. Concentration rates remain slightly below average (90–100% of the average level), and so does the share of animal production.

The level of specialization in genotype III countries is even higher than in genotype II. In this case, self-consumption does not dominate and the level of mixed production is the lowest across all clusters. Other indicators related to specialization, on the other hand, are above average (in the range of 115–133%). It can also be stated that these countries are characterized by a relatively high share of animal production which is additionally highly concentrated, generates a high value of standard output and involves relatively little labor. Genotype IV is the most common and is therefore largely described by indicators close to average levels. Several features of this genotype stand out, most of them negatively. This is especially true for the indicators of average farm size (measured as UAA), employment, production volume and livestock numbers. Interestingly, the distribution rates for this genotype are close to, or slightly higher than, the average which means that in the countries covered, productive inputs are used and distributed in a similar way to other countries but their absolute amounts are smaller. In this situation, the respective deciles had a similar share in the resource pool and production volumes. However, 10% of the smallest farms in the EU had an area of 1 to 5 ha while in genotype IV countries, it was 1 to 2 ha. Another characteristic feature of this group is a high share of households where self-consumption dominates (166% of the EU-27 average).

The descriptive analysis presented above is supported by a statistical approach. The significance of mean differences in particular genotypes was tested. Standard methods used in this kind of assessment require the variance to be constant. However, as demonstrated by the Levene and Brown–Forsythe[4] tests, this assumption was not met for some variables, and therefore the non-parametric Mann–Whitney U test must be used (Table 2).

The results allow to formulate the following generalizations. As regards genotype I, statistically significant differences in mean values were found only for the average farm size, labor distribution, mixed production and livestock distribution. As a consequence, genotype I was identified to be the least differentiated from other ones. However, note that this may also have been influenced by the small number of countries clustered in this genotype, making it difficult to obtain statistically significant results. The largest differences from other clusters were observed in genotype IV countries which differed particularly strongly from genotype III countries (13 out of 16 differences were statistically significant). The main difference between genotype IV and other clusters were the average levels of concentration. The indicators of productive input and production distribution made genotype IV stand out from genotypes II and III, while labor distribution indicators were the differentiating factor between genotype IV and genotype I. Specialization indicators (especially the self-consumption ratio) made genotype IV different from genotypes II and III. The indicators of the distribution of resources and output by production type vary between genotypes II and III, except for the distribution of labor which accounts for the biggest difference between genotypes III and IV. Considering the countries classified into particular genotypes, it can be noted that EU-12 countries (represented mainly by genotype IV) differ significantly from EU-15 countries (represented mainly by genotypes II and III) in the concentration of production and productive inputs. In turn, the differences in dominant lines of production are not so pronounced. At the same time, the EU-15, which demonstrates the characteristics of genotypes II and III, differs mainly in the levels of agricultural production specialization while having a relatively similar degree of production concentration.

[4] At a significance level of $\alpha = 0.05$, the Levene test indicated heteroscedasticity of AVG_UAA, AVG_SO, AVG_AWU, AVG_LSU, SELFCONS, MIXED and AWU_TYPE. The Brown–Forsythe test was performed for AVG_UAA, AVG_SO, AVG_AWU, AVG_LSU and SELFCONS.

Table 2. Mann–Whitney U test results

Features	*p* values for the difference in means between clusters					
	I/II	I/III	I/IV	II/III	II/IV	III/IV
AVG_UAA	0.111	0.533	**0.017**	0.927	**0.000**	**0.003**
AVG_SO	0.889	0.800	**0.017**	0.412	**0.000**	**0.001**
AVG_AWU	0.056	0.267	**0.017**	0.412	**0.025**	**0.005**
AVG_LSU	1.000	0.533	0.150	0.164	**0.001**	**0.003**
UAA_SO	0.056	0.133	0.067	0.788	**0.001**	**0.005**
SO_SO	0.056	0.133	0.067	0.412	**0.020**	**0.025**
AWU_SO	0.056	0.133	**0.017**	0.412	0.971	0.277
LSU_SO	0.056	0.133	0.067	0.648	**0.003**	**0.005**
SELFCONS	0.056	0.133	0.933	0.788	**0.000**	**0.001**
MIXED	0.056	0.133	**0.017**	0.315	0.400	0.079
UAA_TYPE	0.500	0.533	1.000	**0.024**	0.971	0.101
AWU_TYPE	0.889	0.133	0.417	0.109	0.400	**0.018**
LSU_TYPE	0.222	0.133	**0.017**	**0.012**	0.689	**0.012**
ABS_SPEC	0.500	0.133	0.600	**0.024**	0.636	**0.003**
REL_SPEC	0.056	0.800	0.150	**0.006**	**0.031**	**0.025**
ANIMAL	0.222	0.533	0.600	0.648	**0.038**	**0.046**

Statistically significant results at $\alpha = 0.05$ are highlighted in bold.
Genotypes: I: Slovakia, Czech Rep.; II: UK, Sweden, Finland, Austria, France, Germany, Belgium; III: Ireland, Netherlands, Luxemburg, Denmark; IV: Portugal, Poland, Italy, Spain, Malta, Cyprus, Estonia, Romania, Slovenia, Lithuania, Latvia, Greece, Hungary, Bulgaria.
Features: AVG_UAA: average utilized agricultural area; AVG_SO: average standard output; AVG_AWU: average employment; AVG_LSU: average livestock numbers; UAA_SO: land distribution; SO_SO: standard output distribution; AWU_SO: labor distribution; LSU_SO: livestock distribution; SELFCONS: share of subsistence farms; MIXED: share of mixed farms; UAA_TYPE: land distribution by production type; AWU_TYPE: labor distribution by production type; LSU_TYPE: livestock distribution by production type; ABS_SPEC: absolute specialization; REL_SPEC: relative specialization; ANIMAL: share of animal production.
Source: own elaboration based on Eurostat data.

CONCLUSIONS

The results of research presented above can be summarized as follows:

Based on a literature review, agricultural production structures that are likely to have the greatest impact on agricultural productivity were identified. Concentration has a positive effect through economies of scale and greater investment opportunities for large farms. Specialization has a similar effect, mainly due to a reduction in production costs and an increased degree of market compliance. However, the impact of certain lines of production is ambiguous as it depends on differences in productivity between the types of production.

The clustering of countries by structural characteristics resulted in identifying 4 structural genotypes. Genotype I was characteristic of the Czech Republic and Slovakia which can be considered to have a highly concentrated and moderately specialized agriculture with mixed plant and animal production as the dominant line. Genotype II includes the UK, Sweden, Finland, Austria, France, Germany and Belgium. It represents a typical EU level of concentration and specialization. Genotype III is characteristic of countries such as Ireland, the Netherlands, Luxembourg and Denmark where agriculture is a specialized sector with a focus on animal production and an even distribution of productive inputs. Genotype IV comprises EU-12 countries and Southern European countries where production is organized in small farms with many production lines (with a predominance of plant production).

The division of countries coincides to a certain extent with the standard distinction between the EU-12 and the EU-15, except for the Czech Republic and Slovakia which are structurally closer to EU-15 and Southern European countries (Spain, Italy, Greece, Portugal) which, in turn, are closer to EU-12 countries.

While the EU-12 (genotype IV) and EU-15 (mainly represented by genotypes II and III) differ significantly in production concentration and productive inputs (labor, land, livestock), the differences in prevailing lines of production are less pronounced. At the same time, EU-15 countries, characterized by genotypes II and III, differ mainly in the levels of agricultural production specialization while having a relatively similar degree of production concentration.

SOURCE OF FINANCING

Statutory Research Fund of the Department of Macroeconomics and Agricultural Economics, Poznań University of Economics and Business.

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