Dairy processing industry in the European Union: Country-group clustering in pre and post-milk quota abolishment periods

Mlékárenský průmysl v Evropské unii: Skupinové shlukování zemí v období před a po zrušení mléčných kvót

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ABSTRACT

The European Union dairy processing sector has an important position and role in processing food and drinks in EU28 concerning the share of turnover, value-added, and employment. Its products belong to the most imported and exported items, mainly in EU countries. The article aims to evaluate the competitiveness of the EU milk market with respect to pre- and post-milk quota elimination periods. In addition, the paper identifies similar characteristics of the EU dairy sector, including milk production and processing. Eurostat and FAOstat data from 2008-2018 were used. Based on the clustering of k-means, five groups of EU countries were distinguished. The clustering analysis reveals that the post-communist EU member states are characterised by similar levels of dairy processing industry characteristics. In addition, the article shows that the competitiveness of the dairy processing industry is higher in the old EU member states (Belgium, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden and the United Kingdom). The results indicate that the abolishment of the milk quota has not induced visible changes in the clustering of characteristics of the dairy processing industry in EU countries.

Keywords: milk industry, milk production, milk quotas, competitiveness, market orientation, k-means clustering

ABSTRAKT

Odvětví zpracování mléka v Evropské unii má důležitou pozici a roli v odvětví zpracování potravin a nápojů v EU28, pokud jde o podíl na obratu, přidané hodnotě a zaměstnanosti. Mléčné výrobky patří k nejvíce dováženým a vyváženým položkám, převážně v zemích EU. Příspěvek si klade za cíl identifikovat skupinu zemí EU, které se vyznačují podobnými charakteristikami mléčného zpracovatelského průmyslu, a posoudit rozdíly mezi klastry pro období před a po zrušení mléčných kvót. Dále je charakterizován mlékárenský sektor, včetně výroby a zpracování mléka. Ke zpracování byla využita data Eurostatu a Faostatu v letech 2008-2018. Na základě shlukování k-means bylo nalezeno pět skupin zemí EU. Shluková analýza odhaluje, že postkomunistické členské státy EU se vyznačují podobné charakteristiky mlékárenského průmyslu. Rovněž bylo zjištěno, že úroveň konkurenceschopnosti mlékárenského průmyslu je vyšší ve starých členských zemích EU (Belgie, Německo, Irsko, Řecko, Španělsko, Francie, Itálie, Lucembursko, Holandsko, Rakousko, Portugalsko, Finsko, Švédsko a Spojené království). Výsledky naznačují, že zrušení mléčných kvót nezpůsobilo viditelné změny ve shlukování charakteristik mlékárenského průmyslu v zemích EU.

Ključne riječi: mlékárenský průmysl, produkce mléka, mléčné kvóty, konkurenceschopnost, tržní orientace, k-means clustering

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INTRODUCTION

The European Union milk industry has an essential share in the total turnover of the food and drink industry (13%) and value-added (18%). A less significant role is observed in employment (8%) and the number of companies (4%). The dairy industry performs average labour productivity of about 60 thousand euros/person, while the whole food and drink industry is 50 thousand euros/person. The EU dairy products belong to the most imported and exported items, belonging to the most innovative food sectors of the world. Most exports are made within the EU, that is, almost 77% in 2018 (FoodDrinkEurope, 2019), and the top 10 of the top 20 dairy companies in the world are from the EU. Cooperatives and private dairy farms represent the European milk processing industry. They both similarly process about half of the milk processed in the EU (European Dairy Association, 2019).

Our main objective is to evaluate the competitiveness of the EU milk market. An analysis is provided for pre-and post-milk quota abolishment periods division, enhancing the study contribution. Moreover, the milk production and processing sector situation is depicted to reach the complete picture of the whole dairy industry. The quantitative analyses comprehend the dairy processing industry (C10.5), not the milk production market. There is a lack of studies related to country-group clustering in the dairy processing industry to our best knowledge. At the same time, EU milk production disparities are widely researched, see, e.g., Guth (2017) and Poczta et al. (2020).

Milk is one of the most produced and valuable agricultural commodities globally. World trade in milk and milk products accounts for 5% of agricultural commodities. Due to the overall decline in milk consumption in Europe and the self-sufficiency rate of more than 100%, EU milk exports are increasing (Cavapozzi et al., 2020).

The dairy industry in the EU has come through significant structural changes over the years due to price changes, weather, environment, and policy settings (Cele et al., 2021). After the abolition of the milk quota, the European Union has become the largest exporter of dairy products (Budzyńska and Chojnacki, 2018). The abolition of milk quotas in the European Union in 2015 has started a significant expansion in the dairy sector in many countries of the European Union, most notably in Ireland and the Netherlands. However, this increase in production also had wider societal consequences, such as adverse environmental or animal welfare effects (Läpple et al., 2021).

The abolishment of milk quotas in the EU has induced changes in dairy farm size and milk production. In the post milk quota abolition period, some parts of EU dairy farms expanded production (Läpple et al., 2021). Groeneveld et al. (2016) indicate the higher production intensity of milk production. According to Popescu et al. (2019), the milk sector was affected by the milk price crisis by reducing the number of farms and cows and increasing the yield to produce more milk. Farms had to invest in modernisation to obtain better prices and profits. There is a need to invest in farms to stay competitive, adopt technology, and improve labour productivity (Pouch and Trouvé, 2018). Investment in dairy farms helps to adopt new technologies. It also increases efficiency, cost reduction, better product quality, and other environmental effects (Bewley, 2010). Bórawski et al. (2020) find that there has been an increase in milk yield after removing milk quotas. An increase in milk yield should increase total milk production (with the same number of cows for milk production). At the same time, the number of cows and the consumption of dairy products is reduced. Based on these assumptions, the authors assume a 10% increase in milk production in the EU.

Moreover, Kelly et al. (2020) show that farms have become more efficient after quota abolition. The article analyses the impact of the milk quota elimination system on the clustering of EU member states regarding the country's orientation into the dairy processing industry and the competitiveness of the dairy processing industry.

Most studies assess the dairy industry based on farms or firm-level data. Poczta et al. (2020) apply clustering analysis to evaluate the economic situation of dairy farms. They found their research on farm-level data from FADN. Guth (2016) also uses FADN data for grouping EU countries regarding factors determining the variability

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of milk production. The results show various strategies in individual EU countries - it is mainly an expansion, specialisation, or waiting strategy. Using aggregate macro-data in contrast to company-level data allows us to observe a larger sample and extend our coverage.

The paper provides the EU country-group clustering of the dairy processing industry concerning five characteristics, three characteristics related to industry competitiveness and two characteristics regarding market orientation in the analysed sector. Dairy industry competitiveness determines the sustainability and viability of the industry (Michaličková et al., 2014). We are aware that selecting dairy processing industry characteristics regarding its competitiveness is a complex issue, as various indicators could identify it as economic and biological determinants of dairy production (Bohušová et al., 2012).

The milk industry competitiveness is measured by, e.g., milk yield per cow, milk production per hectare, production per one labour unit, or a variety of accountancy indicators. However, since the article focuses on the dairy processing industry, we have selected enterprise productivity, labour productivity, and investment variables. Danilevičienė (2018) and Novak and Krukowski (2019) indicate that labour productivity is critical for enterprise competitiveness. Labour productivity is a widely used indicator to compare the competitiveness of sectors (Jansik and Irz, 2015). Atkinson (2013) states that increasing productivity reduces costs and sells more on markets. Kleinhanss (2015) identifies that higher capital increases labour demand and wages. The growth of productivity and wages has become an essential factor influencing international competitiveness. The investment could also affect the competitiveness of enterprises (Pilinkienė, 2015).

The paper analyses how the abolition of milk quotas has affected the disparities in the characteristics of the dairy processing industry among EU member states. Schulte et al. (2018) show that the volatility of milk prices after the abolition of milk quotas affects the volume of investments in new milk production and processing technologies.

MATERIAL AND METHODS

Our main objective is to evaluate the competitiveness of the EU milk market. An analysis is provided for pre- and post-milk quota abolishment periods separately, enhancing the study contribution. Moreover, the milk production and processing sector situation is depicted to reach a complete picture of the dairy sector. In the study, the following research questions are formulated.

Research question 1: Post-communist EU member states are characterised by similar levels of dairy processing industry characteristics.

Research question 2: The abolishment of the milk quota has not induced changes in the country grouping in relation to the characteristics of the dairy processing industry.

Evaluation of selected indicators is done for all EU (EU28, incl. United Kingdom) member states for the period 2008-2018, the most extended available period for selected indicators. The central part of the research is based on a cluster analysis of the characteristics of the dairy processing industry characteristics in EU member states. Three determinants of attributes of the dairy processing industry were used that is, labour productivity, wages, and investments. Labour productivity was calculated as gross value added per employee. Investments are defined as gross investments in tangible goods per person employed. Wages include all payments to employees to which the corresponding taxes and social security contributions are paid (gross earnings) per employee. In addition, two determinants regarding market orientation in the dairy processing industry were applied. Share on a number of enterprises represents the share of enterprises operating in the milk industry (C 10.5) on a total number of enterprises in food processing (C 10). The production share represents the share of milk production in total food processing production.

Clustering analysis was performed by applying the k-means algorithm developed by Linde, Buzo, and Gray (1980). The k-means method aims to find the nearest distance of points from the cluster's centre (Ding and He, 2004).

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Dunn's connectivity-based cluster validity index detects the optimal number of clusters. Moreover, the Kruskal-Wallis test (Kruskal and Wallis, 1952) investigates significant differences between five distinguished sets of EU country groups.

The research is conducted separately for pre-and post-milk quota abolishment periods. Clustering analysis is based on 2011-2018 annual data to maintain the balance of period length. The data used for the analysis is in Appendices A1 and A2.

Eurostat data (2020b) on the number of milking cows, total milk production, and the milk production delivery ratio were used. We base our data on Eurostat collections for the dairy processing industry, particularly data related to NACE C10.5, manufacture of dairy products; also referred to as the dairy industry or just C10.5. Also, data on the manufacture of food products (C10 or food industry). Data were collected primarily from Eurostat (2020a, 2020b) and FAOstat (n.d.).

RESULTS AND DISCUSSION

Milk production in the EU

In the European Union, the total amount of milk produced increases constantly on average by 1% a year (as shown in Table 1), with the only exception of 2009, when a decrease in production was observed. It means that the milk sector was affected by the economic crisis, and there was an increase in food prices on the market (Bojnec and Ferto, 2014). After 2015, the EU quotas were phased out, and the restrictions on the import of milk products from outside the EU were relaxed (Parzonko and Bórawski, 2020); as it was pointed out, the quotas can affect the dynamics of the industry, competitiveness, and productivity (Jorgenson and Timmer, 2011). In the EU market, the quota had a negative effect on productivity (Gillespie et al., 2015). After quota elimination, EU milk production was on growth.

Dairy cows are the most important source of milk in the EU28, providing about 152 million litres to dairies, while all other milk deliver to diaries makes only 4 million litres. This imbalance is not reflected in the number of animals. During the period, the number of milking animals decreases by more than 3 million pieces, and the trend reaches 57 million, of which 22.9 million count dairy cows. Over the years, a decrease in dairy cow numbers of about 1.5 million (-6%) was observed. The average European cow productivity is higher by 1,300 litres compared to 2008.

Table 1. Milk production characteristics in the European Union (EU28)

EU 28	08-10 average	11-14 average	2015	2016	2017	2018	AAGR
Raw milk, total available on farms (ths. l)	149,433	154,494	163,072	163,730	165,514	167,034	1.1 %
- Cow-milk, ths. l delivered to dairies	130,904	138,047	147,316	147,668	151,335	152,108	1.5 %
- Ewes' milk produced on farm (ths. l)	2,627	2,609	2,685	2,727	2,681	2,759	0.7 %
- Goats' milk produced on farm (ths. l)	2,104	2,100	2,121	2,209	2,231	2,269	1.0 %
- Buffaloes' milk produced on farm (ths. l)	231	244	254	257	262	266	0.8 %
Number of dairy cows (ths. heads)	23,863	23,309	23,57	23,532	23,313	22,908	-0.6 %
Cow productivity (litres)	5,657	6,105	6,443	6,469	6,692	6,845	2.2 %
The number of other milk giving animals1 (ths.)	36,268	34,466	34,429	34,315	34,493	34,438	-0.5 %
Delivery ratio (%) 2	90	92	93	93	94	94	0.4 %

[1] Goats mated and having already kidded; Breeding female buffaloes; Milk ewes and ewe-lambs put to the ram

[2] Delivery ratio is milk delivered to dairies per total production

Table 2 shows that five countries have a dominant position in the EU dairy cow stocks – Germany (18%), France (15%), Poland (10%), the United Kingdom (8%), and Italy (8%). Altogether, they account for almost 60 % of dairy cows within the EU28. The Netherlands and Ireland are other very significant milk producers, which belong to smaller EU28 countries, but their share in the number of dairy cows is 7 and 6%, respectively. Seven countries reveal an increase in dairy cows, especially Ireland.

Table 2. Milk Production Characteristics in the EU Member States

	The number of dairy cows (ths.)		Raw milk, total available on farms (ths. litres)		Productivity (litres/cow)		Share of cow milk on total milk production	Self-sufficiency rate
	2008	2018	2008	2018	2008	2018	2018	2017
Belgium	517.8	529.3	2,892.0	4,219	5,503	7,896	99.0%	110%
Bulgaria	314.7	244.4	1,316.0	1,025.2	2,163	2,655	63.3%	80%
Czechia	399.7	358.6	2,801.3	3,161.64	6,086	8,458	95.9%	129%
Denmark	566.0	570.0	4,656.0	5,615.2	8,102	9,851	100.0%	217%
Germany	4,229.1	4,100.9	28,691.3	33,109.66	6,494	7,923	98.1%	125%
Estonia	100.4	85.2	694.2	797.6	6,035	8,781	93.8%	157%
Ireland	1,024.1	1,369.1	5,113.7	7,831.25	4,970	5,705	99.7%	208%
Greece	154.0	95.0	1,891.7	1,844.9	4,482	6,528	33.6%	71%
Spain	888.3	816.7	7,286.6	8,417.53	6,585	8,719	84.6%	78%
France	3,857.0	3,554.2	25,107.6	26,012.26	6,175	6,905	94.3%	133%
Croatia	212.6	136.0	848.0	634	3,094	3,334	71.5%	64%
Italy	1,830.8	1,939.5	12,115.8	13,131.64	5,730	6,224	91.9%	81%
Cyprus	23.6	31.9	195.0	294.64	6,364	7,154	77.4%	134%
Latvia	170.4	144.5	835.5	982.9	3,725	5,403	79.4%	167%
Lithuania	394.7	256.2	1,883.8	1,571.84	3,502	5,334	86.9%	114%
Luxembourg	45.9	53.0	:	410.9	5,763	7,449	96.1%	390%
Hungary	263.0	239.0	1,845.7	1,953.76	5,419	6,424	78.6%	97%
Malta	7.3	6.2	42.8	43.23	N/A	6,486	93.5%	65%
Netherlands	1,587.0	1,552.0	11,797.5	14,426	6,891	8,944	96.2%	196%
Austria	530.2	532.9	3,221.1	3,859.99	5,102	5,973	82.5%	129%
Poland	2,696.9	2,214.1	12,445.0	14,179.21	3,379	5,395	84.2%	124%
Portugal	264.8	235.5	2,141.9	2,040.29	7,138	8,044	92.8%	86%
Romania	1,483.3	1,158.2	5,494.0	4,443.3	710	958	25.0%	89%
Slovenia1	113.5	102.7	655.7	631.22	4,622	5,456	90.5%	124%
Slovakia	173.9	127.9	1,066.3	917	5,441	6,399	89.2%	75%
Finland	288.4	263.6	2,310.9	2,397.88	7,817	8,928	98.2%	95%
Sweden	365.6	313.1	2,986.6	2,760.23	8,082	8,817	100.0%	93%
United Kingdom	1,903.0	1,879.0	13,722.1	15,488.11	7,015	8,083	98.1%	91%
EU 28	24,405.8	22,908.5	154,058.0	172,200	5,523	6,845	91%	116%

[1] Slovenia 2018 value is not available; the presented value is a mean of 2017 and 2019

According to Zeng et al. (2017), the reason is the increase in the size of the herd after quota elimination. Significant growth was also evinced in Cyprus. It is obvious how farmers in some countries used the opportunity and convenient conditions to increase milk production by increasing the number of cows after eliminating quota (Janecká et al., 2019). After 2014, a significant decline in the total number of dairy cows was observed in Germany, Italy, and France. Rosa et al. (2016) explained that the dairy sector was protected from world competition under the quota regime, and after 2015, structural changes were required. Industry expected a decline in the raw milk prices due to milk supply growth. As the scale of production impacts economic efficiency, Parzonko and Bórawski (2020) predict a reduction and further consolidation of dairy farms in the EU.

Concerning quota abolition, between 2014 and 2018, 22 countries experienced a decrease in cow heads of approximately 900 thousand, mainly observable in Germany, France and Italy. Due to changes in ownership, EU leaders in the milk industry entered the country and contributed to restructuring dairy processors.

The delivery ratio (Table 1) continuously increases throughout the period. This indicator is affected by higher production per cow, farm specialisation in milk production, and aspects of competitiveness related to economies of scale. In 2018, approximately 94% of milk was delivered to the diary (Eurostat, 2020b).

The most crucial milk producers are parallel with the significant dairy cow breeding countries. As Bórawski et al. (2020) indicated, ten countries dominate milk production. Our data shows that Germany, France, Poland, the Netherlands, and the UK generate about 58% of milk production. The position of the top five largest producing countries is more or less stable. However, there are more considerable differences in cow productivity. Farmers in Denmark should reach 10,000 litres per cow/year in the coming years, followed by the Netherlands, Finland, and Sweden. EU 28 average value of 6,845 l/head is located in the exact median. The worst performance reached the milking sector in Croatia, Bulgaria, and Romania.

Interestingly, according to our analysis of Eurostat data, Romania shall have annual productivity below 1,000 l per head of dairy cows. However, the Romanian National Institute of Statistics states that Romanian productivity should be above 3000 l / head (Popescu, 2017). In Romania and Greece, farmers breed a large portion of other milking animals than cows providing about 75% and 66% of milk, respectively.

Dairy processing industry in the EU

As raw milk is a fast-spoiling commodity, its natural characteristics do not allow for comprehensive transport in EU28. Thus, national markets and border regions are somewhat dependent on regional supply. Fresh raw milk is imported into the EU and exported out of the EU in minimal amounts. Figure 1 shows that the milk produced in the EU is processed mainly in dairy. The minimum is processed on farms (only 7%). The dairy industry generates fresh products (drinking milk) and processing products (cheese, butter, milk powder, whey, etc.).

The performance of the member countries is balanced. No country in the EU has a highly dominant position over other countries in milk production or processing. However, it should be stated that the results do not indicate market concentration in particular markets (among the local dairy processing entities). However, in the literature, it can be observed that the authors name some countries as less concentrated (Čechura et al., 2015) - Bulgaria, the United Kingdom, Ireland, Lithuania, and Sweden, while in other markets, dairy producers exercise a higher degree of noncompetitive behaviour (Austria, Hungary, Finland, and Portugal, The Netherlands).

The number of dairy enterprises is not high (Table 3); milk processing is a concentrated activity compared to other subindustries of food manufacturing. Average EU dairy facility processes about 12.6 thousand litres of milk annually, but significant differences were observed. Tacken et al. (2009) observed different market concentrations in France, Germany, Italy, Poland, and the Netherlands. While the three largest dairy manufacturers had a 77% share in dairy sales, in the Netherlands, it was only 27% for the four
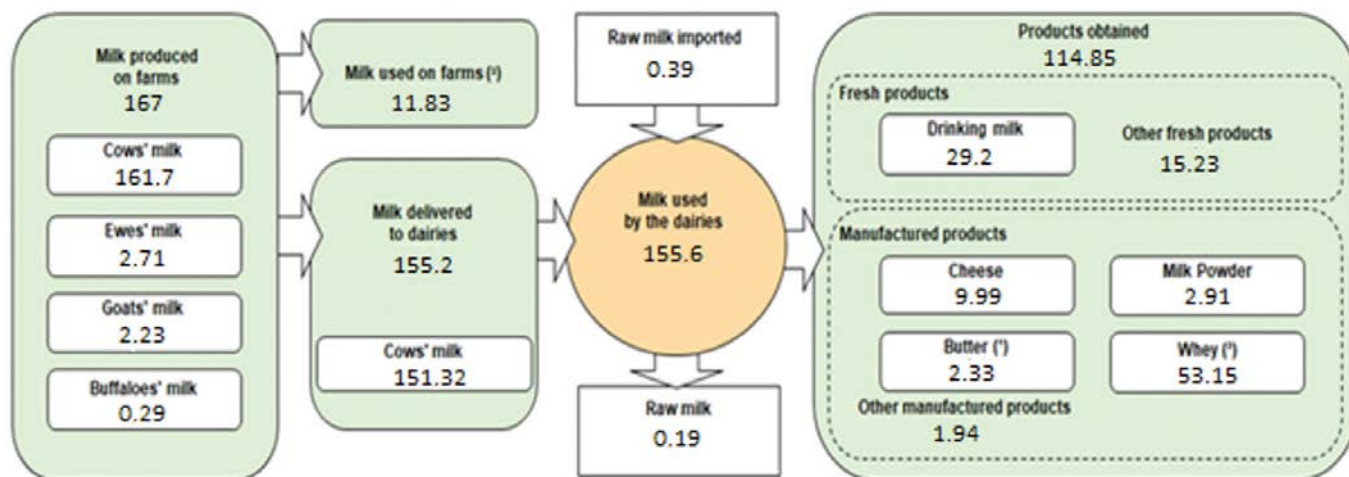
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Figure 1. Dairy value chain in EU, 2018 (million litres) according to Eurostat (2020b)

largest dairies in Poland. This implicates one of the major issues – the size differentiation of dairy plants. While huge producers (Lactalis, Arla Food, FrieslandCampina, etc.) reach a significant market share, many micro (farm) dairy processing entities have a negligible market position. During the period under review, 1,271 enterprises were established (an 11% increase), most of which are expected to be microenterprises (Table 3).

Within individual countries, three scenarios can be identified: growth, stagnation, or decline in the number of dairy entities. A relatively stable number of companies is evident in the case of Belgium, Czechia, Denmark, France, Malta, and Romania. A significant adverse change in companies is observed only in Croatia, Cyprus, and Lithuania.

On the contrary, milking cow number and milk production show the fastest growth dynamics with Ireland in Cyprus. According to CLAL (2020), Cyprus's increase in production was primarily driven by the export of Cypriote cheese.

Table 3. Characteristics of the dairy industry in the European Union (EU28)

EU 28 (C10.5 if not indicated otherwise)	08-10 average	11-14 average	2015	2016	2017	2018	AAGR 2008 – 18[3]
Number of enterprises	11,925	12,377	12,773	12,839	13,049	13,266	1.0 %
Production value (million EUR)[1]	115,232	132,175	132,474	130,580	150,754	150,027	2.0 %
Share of the.5 on the C10 production value of C10	16 %	16	15 %	14.7 %	16.1 %	16.1 %	-0.4 %
Salaries paid (mill. EUR) *	7,785	9,011	9,855	10,156	11,807	12,144	6.1 %
Number of employees[2]	285,337	323,643	329,326	331,353	365,415	N/A	3.0 %
Share of C10.5 employees on C10 (%)	9	9	9.4	9.2	9.9	N/A	1.1 %
Average annual salary per employee (ths. EUR)	27	28	29.9	30.6	32.3	N/A	3.4 %
Investments (mill. EUR)	2,816	3,622	4,061	3,972	3,611	N/A	3.2 %
Share of C10.5 investments in C10 (%)	12.8	293	15.7	15.7	13.3	N/A	2.2 %
Gross value added per person employed (ths. EUR)[3]	N/A	58	60	60	60	N/A	

[1] Malta, Denmark and Luxembourg NOT included
[2] Malta, Denmark, Slovenia and Luxembourg NOT included
[3] 30% higher productivity of C10.5 compared to C10

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The third scenario reflects growth in the number of dairy entities (the most significant addition is observed in Poland, Spain, Germany, Slovenia and the United Kingdom.

The total EU28 production value of dairy manufacturing increased by 2.3% per year and was not driven by increased labour productivity at the EU level. The total number of dairy employees increased by 3.1% per year. EU production per employee is on a downward trend. However, the negative result is determined by changes in France (-4.17% p.a.), Spain (-0.58% p.a.) and Croatia. All other countries reveal growth. However, because Spanish and France entities play an essential role in the whole sector and employ a significant portion of labour (together 28%; more than 100,000 employees), their labour losses negatively affect the entire EU. The dairy industry has higher labour productivity of approximately 30% compared to other subsectors of food manufacturing (C10). Investments are one of the critical factors that affect and contribute to higher labour productivity (as confirmed, for example, by Náglová et al., 2016). They can contribute to the stabilisation of profits and increase competitiveness (Špička, 2015). From the perspective of other food subsectors, EU dairy is investment intensive – contributes to about 15% of all food investments in the EU.

Wages and salaries are other important factors related to the dairy industry. From 2008 – to 2017, an increase in the average wage is evident in most evaluated countries. The most significant decrease occurred in Greece. In contrast, the most significant growth is noticeable in Bulgaria, where average wages increased by 58%.

Western and Northern Europe represents older EU members. The highest average wage is provided in Denmark, Netherlands and Belgium and ranges from 50 to 55 EUR. The results confirm the general theoretical assumptions that wages shall be linked to productivity.
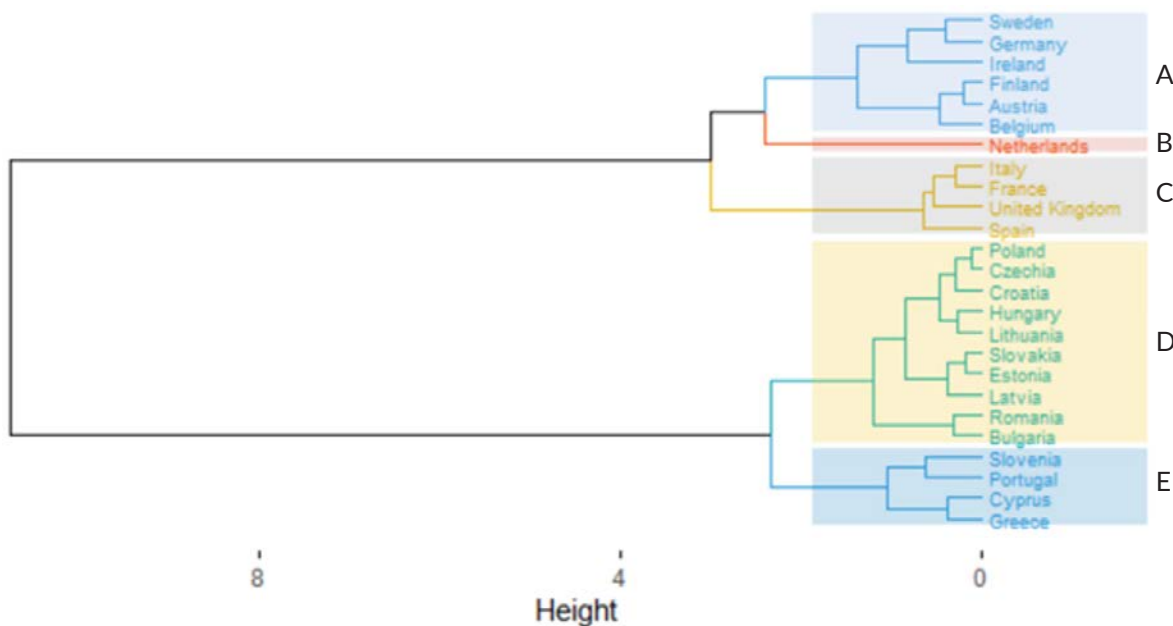
K-means clustering analysis

As the clustering of milk production in the EU28 countries is broadly researched in many studies, this study focuses on the dairy processing industry. Paper analyses dairy processing industry characteristics in 25 out of 28 EU countries due to the lack of data for Denmark, Luxemburg, and Malta. As the research period covers the 2008-2018 years, it is considered data for the United Kingdom, as it was an EU member state. Clustering analysis based on the k-means algorithm for five selected determinants was performed, referring to the market orientation into the dairy industry and dairy industry competitiveness. Dunn's connectivity-based cluster validity index for different clusters indicates that the optimal number of clusters is five. The research is conducted separately for pre and post-milk quota abolishment periods. K-means clustering presented in Figure 2 indicates the existence of significant differences in diary industry characteristics between the distinguished country groups in the pre-milk quota abolishment period. The dendrogram (Figure 3) shows the groups in which the countries are combined based on similarities in the market orientation of the dairy industry and the competitiveness of the dairy industry. For instance, Poland and Czechia are the closest in the dendrogram, implying they are the most similar EU member states, while the Netherlands is the further from other countries, i.e., it differs the most.

Cluster A1 includes Sweden, Germany, Ireland, Finland, Austria, and Belgium. Cluster B1 includes only the Netherlands. Italy, France, the United Kingdom, and Spain belong to cluster C1. Clusters A1, B1, and C1 are composed of only old EU member states. Cluster D1 refers to ten new EU member states with post-communist heritage: Poland, Czechia, Croatia, Hungary, Lithuania, Slovakia, Estonia, Latvia, Romania, and Bulgaria. Cluster E1 contains south EU countries, Slovenia, Portugal, Cyprus, and Greece. To verify whether the differences between the distinguished five clusters are statistically significant, the Kruskal-Wallis test was applied.

Table 4 results indicate statistically significant differences in median values of three analysed dairy processing industry characteristics between at least two of five distinguished EU country-group clusters. It was discovered that the gross labour productivity, wages, and investment were significant at a 1% significance level.

Figure 2. K-means clustering for pre-milk quota abolishment period (2011-2014)

However, there were no significant differences in median values of dairy enterprise share and dairy production share among distinguished clusters. Kruskal-Wallis test results indicate that the analysed determinants regarding competitiveness significantly affect the country differentiation of the EU dairy processing industry. In contrast, factors related to market orientation in the dairy processing industry in the EU countries do not induce disparities among clusters.

Figure 3 depicts the significant differences among clusters regarding labour productivity, wages, and investments. The Netherlands, the only EU country belonging to cluster B1, is characterised by the highest values of all three analysed dairy processing industry characteristics, i.e., labour productivity, wages, and investment. Clusters A1 and C1 also represent the old EU member states with relatively high levels of the above-mentioned dairy variables. However, the average level of investment in cluster A1 is higher than in cluster C1. Clusters D1 and E1 are characterised by the lowest levels of dairy processing industry characteristics.

Nevertheless, group D1, which consists of only new EU member states, reaches lower levels than cluster E1, representing mostly small southern old EU countries. The results presented in Figure 3 might imply that the length of EU membership positively affects the dairy processing industry's competitiveness, while the post-soviet heritage refers to the reverse effect. It is in line with research question 1.

K-means clustering presented in Figure 4 indicates the existence of significant differences in diary industry characteristics between the distinguished country groups in the post-milk quota abolishment period. The results suggest that the milk quota abolishment has not induced

Table 4. Results of Kruskal-Wallis and Wilcoxon rank-sum pairwise comparison for pre-milk quota abolishment period

Category	Share on number of enterprises	Production share	Labour productivity	Wages	Investment
Kruskal-Wallis test					
K-W chi-square	2.9569	1.6292	21.238	21.862	19.241
p-value	0.5651	0.8035	0.0003	0.0002	0.0007

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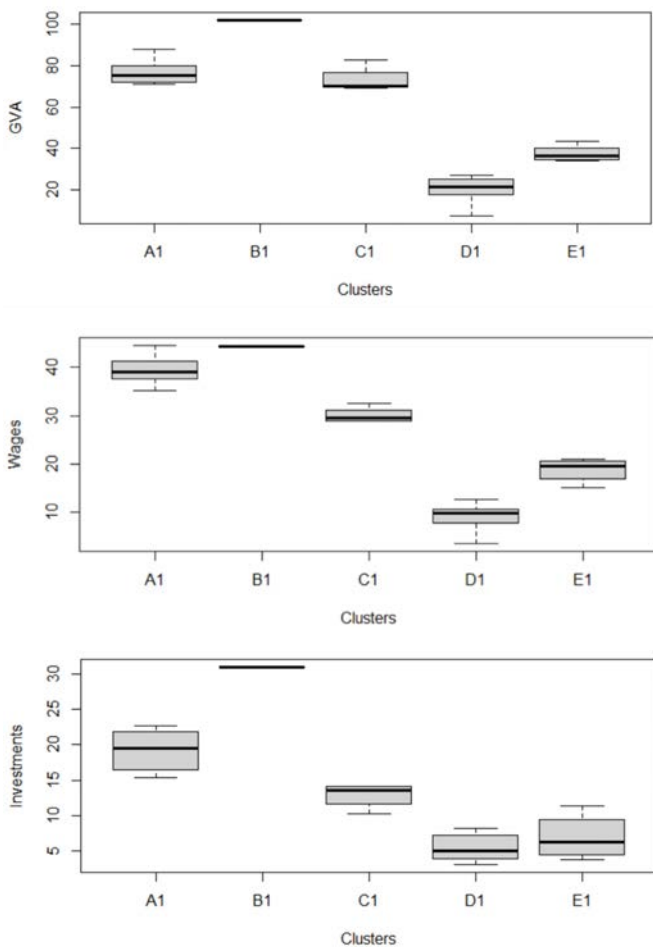
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Figure 3. Boxplots of labour productivity, wages, and investment in the pre-milk quota abolishment period

visible changes in the clustering of dairy processing industry characteristics in EU countries. However, there were observed a few movements among five distinguished clusters. It corresponds to research question 2.

Cluster A2 includes Finland, Austria, Germany, and Belgium. Sweden and Ireland joint cluster C2, which also consists United Kingdom, France, Italy, and Spain. The Netherlands remains the furthest from the other EU member states and independently forms the cluster B2. Similar to the pre-milk quota abolishment period, clusters D2 and E2 are almost the same in the post-milk quota abolishment period. The only cluster change refers to Portugal, from E2 to D2. A1, B1, and C1 are composed of only old EU member states. Table 5 results indicate statistically significant differences in median values of four analysed dairy processing industry characteristics between at least two out of five distinguished EU country-group clusters.

Similar to the pre-milk quota abolishment period, labour productivity, wages, and investment are significant in differentiating clusters at a 1% significance level. Moreover, it was observed that milk quota abolishment might have induced significant differences in market orientation in the dairy processing industry among clusters at a 10% significance level.
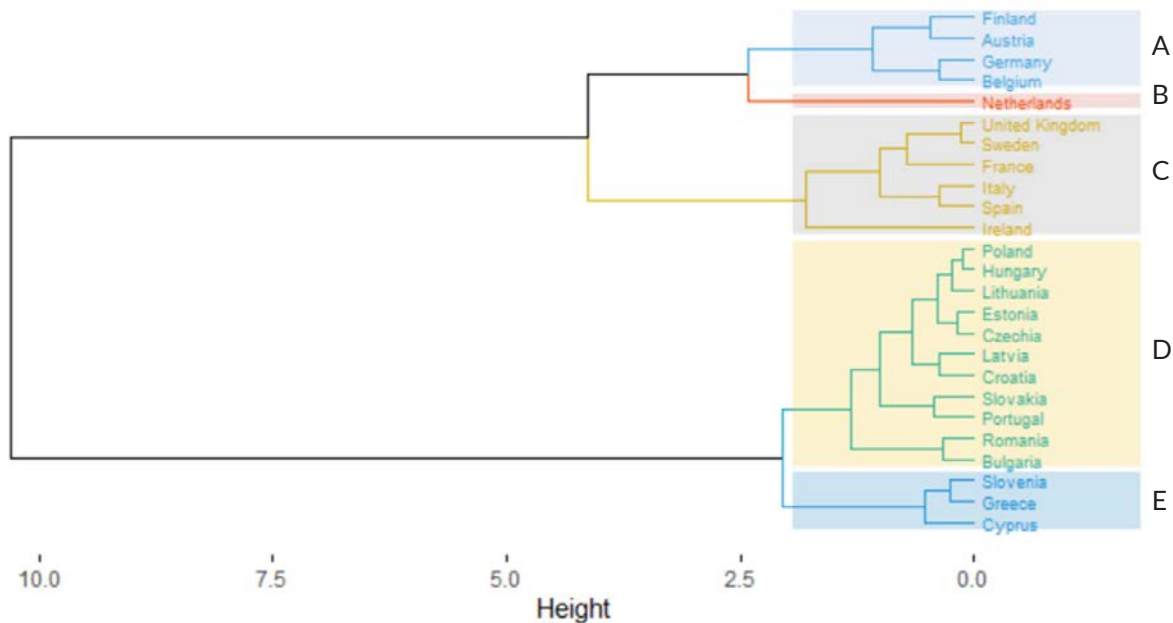

Figure 4. Post-quota abolition clustering based on data (2015-2018)

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Table 5. Results of Kruskal-Wallis and Wilcoxon rank-sum pairwise comparison for post milk quota abolishment period

Category	Enterprises share	Production share	Labour productivity	Wages	Investment
Kruskal-Wallis test					
K-W chi-square	8.3852	4.4035	20.478	20.902	15.862
p-value	0.0784	0.3541	0.0004	0.0003	0.0032

However, it concerns only one analysed determinant, i.e., enterprise share. No significant differences in median values of dairy production share among clusters were observed. As in the 2008-2014 period, Kruskal-Wallis test results indicate that the analysed determinants regarding the dairy processing industry's competitiveness differentiate distinguished EU country groups.

Figure 5 shows the significant differences among five clusters regarding enterprise share, labour productivity, wages, and investments. Boxplots for all three analysed determinants of dairy processing industry competitiveness strictly correspond to those for the pre-milk quota period. The highest values of all three determinants mentioned above refer to the Netherlands (cluster B2); the average levels refer to clusters A2 and C2, while the lowest levels - clusters D2 and E2. However, the values of a determinant of market orientation in the dairy processing industry, i.e., enterprise share, are not in line with the boxplots for dairy market competitiveness determinants and reveal substantial differences within clusters.

CONCLUSIONS

Historical policy changes and international consequences have affected the situation in the European Union dairy market. Over the analysed period, the market has transformed from quota-based to unregulated. Many changes occurred at the milk production (farms) and milk processing (dairies) levels. It is crucial to assess the situation in the dairy industry, which provides needed products for the population and generates demand at the farm level.

The primary milk production and processing sector situation was depicted to reach a complete industry picture. Market insight allows us further to identify a group
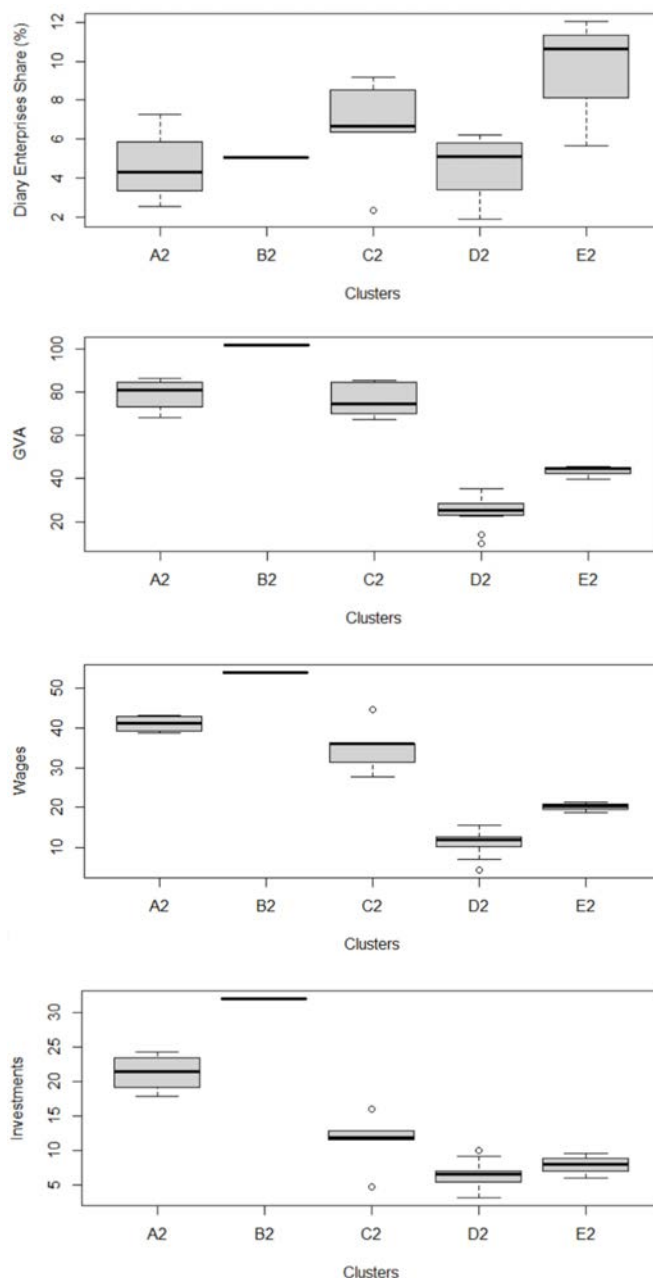
Figure 5. Boxplots of enterprises share, labour productivity, wages, and investment in the post milk quota abolishment period

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of EU countries characterised by similar dairy processing industry characteristics related to production efficiency and competitiveness. The division of pre and post-milk quota abolishment periods was analysed, enhancing the study contribution.

Our clustering analysis is based on 2011-2018 annual data on key dairy processing industry characteristics for EU member states. The research is conducted separately for pre and post-milk quota abolishment periods.

Based on the k-means clustering, five EU country-groups characterised by a similar level of dairy processing industry characteristics were distinguished. The clustering analysis reveals that the post-communist EU member states are characterised by similar levels of dairy processing industry characteristics. The results are in line with research question 1. Moreover, the paper showed that the dairy processing industry competitiveness is higher in the old EU member states. The results indicate that the abolishment of the milk quota has not induced visible changes in the clustering of characteristics of the dairy processing industry in EU countries. It corresponds to research question 2.

The Kruskal-Wallis test results for the pre-milk quota abolishment period show statistically significant differences in median values of dairy processing industry competitiveness characteristics among distinguished clusters. However, determinants of market orientation appear to be insignificant. Similar to the pre-milk quota abolishment period, in the post-milk quota abolishment period, it was found that labour productivity, wages, and investment were significant in differentiating distinguished clusters. Moreover, significant differences in market orientation in the dairy processing industry among clusters were observed.

The authors are aware of our study's drawbacks. Firstly, the selection of dairy processing industry characteristics might be judged to be subjective. Secondly, the number of analysed determinants is limited. Thirdly, our EU country clustering does not contain Denmark, Luxemburg, and Malta due to data availability.

A challenge for future research is conducting the clustering analysis based on broader dairy processing industry characteristics using national databases and assessing the COVID-19 pandemic impact on the competitiveness of the dairy processing industry in the EU member states.

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