

CLUSTER ANALYSIS OF THE DAIRY SECTOR IN EUROPE

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Abstract

The European dairy sector has an important role in the global agricultural market and is influenced by various economic, political and environmental factors. The aim of this study is to analyse the structure and market dynamics of the dairy sector in European countries using cluster analysis. The study uses Eurostat (2023) data, which were grouped in 3 categories: dairy production capacity, market dynamics and economic and demographic indicators. The study uses factor analysis and hierarchical clustering methods to identify similarities and differences across European countries based on dairy production levels, trade balance and macroeconomic environment. The results reveal significant differences in the European dairy sector, highlighting that countries with well-developed production systems have a greater export orientation. The cluster analysis shows that Central and Western European countries demonstrate higher efficiency and stronger market performance, while Eastern and Southern European countries show lower competitiveness due to structural and economic constraints. The results suggest that specific policy measures are needed to improve the resilience of the dairy sector, especially in regions facing production and market challenges.

Keywords: factor analysis, cluster analysis, dairy sector, Europe.

Introduction

European countries are major players in the world dairy markets, and dairy farming is one of the most profitable agricultural sectors in the Europe (Arendok & Liinamo, 2003). Accordingly, European countries compete with large dairy producing countries (e.g. China and Brazil); therefore, it is essential that the European dairy industry follows the trends in this sector, as well as for the sector to be developed. Another factor to be considered is that on a global scale the dairy industry is probably one of the most distorted agricultural sectors, exposed to various crises (e.g. environmental, social and economic crises) (Knips, 2005; Pappa, 2019). This is due to the fact that the sector is influenced by both external factors (e.g. Covid, the Russian-Ukrainian war), as well as political decisions made at the Europe Union (EU) level (e.g. the introduction and later abolition of quotas), and the sector is also influenced by the internal regulations of each individual European country and even the geographical location of the country. Furthermore, the sector can vary within a country and across regions (Otte & Chilonda, 2006). Overall, the dairy sector has undergone several structural changes over the past 20 years, driven by rapid technological developments and intense policy interventions (Rytönen et al., 2020). Such EU actions are partly due to the fact that the world population continues to grow and there is a tendency to consume more dairy products in the regions that historically had lower dairy consumption, e.g. Asia. So the dairy sector needs to adapt to ensure a greater supply of livestock products and improve the efficiency of the sector, while paying attention to animal welfare and balancing environmental sustainability, e.g. emissions reduction policy (in line with the European Green Deal). To achieve these goals (i.e., to ensure a greater supply of products and improve the efficiency of the sector), as already mentioned, technologies and farming practices are being developed to make milk production more efficient (for example, automated feeding systems, milking robots and various manure management solutions are being

introduced on farms), and cows with high genetic potential are also being selected to increase their milk production during lactation, thus ensuring the goal set by the farms – to increase productivity indicators (Neethirajan & Kemp, 2021). The EU offers farmers various subsidy options that directly promote technological development and, accordingly, the competitiveness of the sector. Since the sector is subject to various types of influences, it is important to identify the factors that affect milk production, as this helps to monitor and predict how the sector is changing (Otte & Chilonda, 2006). These factors are especially important for policymakers who would create short-term or long-term policy planning documents based on such data. The dairy sector can be analysed using various indicators, and some of the main indicators are the total number of dairy farms, the number of dairy cows per farm and the average milk yield per cow. In general, milk yield per cow is widely accepted as the primary measure of farm productivity, as it reflects the efficiency of dairy operations and the effectiveness of herd management practices (Viira et al., 2015). However, another significant factor indicating changes in the dairy sector is the structural composition of dairy farms. Such an indicator provides valuable insight not only into the distribution of herds, but also into the overall efficiency and sustainability of the sector. For example, there are countries with intensive dairy production sectors, with a larger number of cows (300 and more) dominating, but there are also countries where the number of large farms is decreasing and the number of small farms (up to 50 cows) is increasing. Such trends may indicate, for example, that larger farms are more likely to adopt new technologies faster and invest in their integration into their farms, thereby increasing production volumes and achieving higher productivity. In addition to production capacity, market conditions also significantly affect the profitability of the dairy sector (Otte & Chilonda, 2006). External influences, such as global market instability, fluctuations in feed costs, changes in transport logistics,

also affect the dairy sector in Europe, affecting farmers’ incomes and the resilience of the sector (Bórawska et al., 2021). It is also important to remember that production volumes and milk prices are interrelated, reflecting the interaction of market supply and demand. Milk prices vary around the world, as they are influenced by various economic, social and environmental conditions, the average number of dairy cows on the farm and the average milk yield, supply/demand relationships, the level of production per capita, as well as various political circumstances (Popescu et al., 2019).

Identifying trends in farm structure, production efficiency and market dynamics helps policymakers and stakeholders to develop targeted strategies that support the sustainability of the sector and its ability to adapt to new challenges.

Materials and Methods

Data were collected from Eurostat (Eurostat, 2023) and are grouped in 3 categories - Dairy Production Capacity,

Market Dynamics and Economic and Demographic Indicators (Table 1). Data is gathered for all EU countries for the year 2023.

To optimise the further calculations, in particular cases, when data for 2023 is missing for individual countries, it is replaced by the data from the same indicator and same country for the previous years or a neighbouring country if they have been comparable considering the historic data. The group Dairy Production Capacity focuses on factors that influence the overall capacity of dairy farming, such as the number of dairy cows, milk collection, and the production of various dairy products (for example cheese and butter). The group Market Dynamics includes economic and trade-related indicators that influence the pricing, cost structure, and trade balance of dairy products.

And the group of Economic and Demographic indicators provide insight into how economic growth, employment trends, and population dynamics influence the dairy sector.

Table 1

Data classification

Group	Indicator
Dairy Production Capacity	number of dairy cows; collection of cow’s milk; milk treated-distribution; production of cheese; production of butter; production of acidified milk; skimmed milk powder; whey; organic cows raw milk prices
Market Dynamics	selling prices of milk; selling prices of crop products; fresh milk export; fresh milk import; compensation of employees; agricultural land prices
Economic and Demographic	GDP per capita; growth in GDP; employment rate; unemployment rate; share of GV, agriculture; share of employment, agriculture; population change; population; area

The indicators were further used in this study for the factor analysis and cluster analysis described further in the Results and Discussion section, this was done by using the IBM SPSS Statistics 30.0.0.0 software.

Results and Discussion

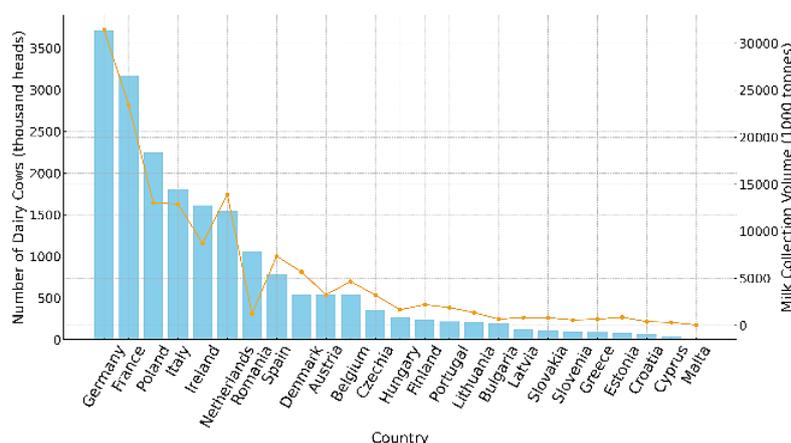
By examining the individual indicators included in Table 1, it is possible to observe some of the main indicators that affect the dairy industry. Further, the

article assesses and compares such indicators as the total number of cows, milk yield per cow, fresh milk imports and exports, as well as milk prices in Europe (Figure 1, Figure 2, Figure 3).

Figure 1 shows the relationship between the number of dairy cows (represented by bars) and the volume of milk collected per cow (represented by a line) in EU member states (excluding Sweden and Luxembourg, as data were not available for these countries).

Figure 1

Dairy cows and milk collection volume in Europe (2023)

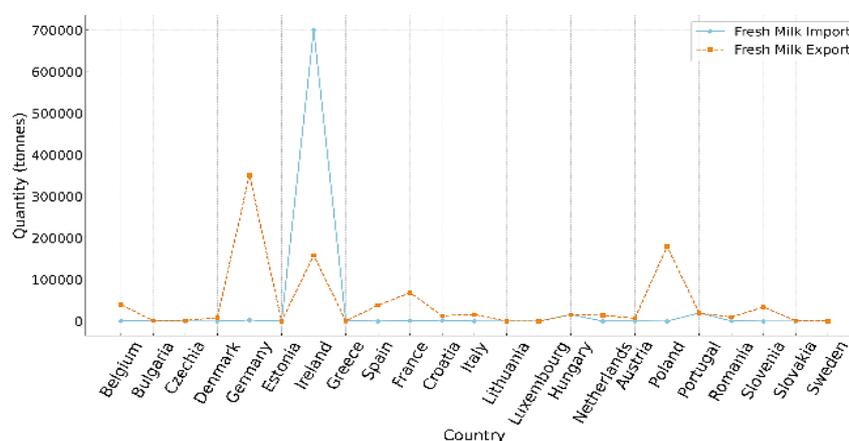


Countries with larger number of dairy cows have a higher volume of milk collected, indicating a direct relationship between herd size and production capacity. However, some differences also indicate differences in productivity and efficiency between countries. For example, in some countries (e.g. the Baltic states) the average milk yield per cow is higher than the number of cows being milked. Such dynamics may indicate improvements in the efficiency of the industry. Such a trend may be explained by the fact that farmers began to run productive livestock more accurately and select cows with the highest genetic potential, which can produce more milk during lactation. Genetic selection has led to significant increases in milk yield, which in turn has increased the

productivity of the dairy industry. However, it also has negative consequences, for example, cows that have been genetically selected for higher milk yield are more likely to suffer from health problems such as mastitis, metabolic disorders and reproductive problems (Hansen, 2000; Berry et al., 2003).

The dairy market is very dynamic and is influenced by various factors: economic factors (e.g. GDP and income levels), trade policies and regulations (e.g. tariff policy), geographical and logistical factors and market structure, and production factors (e.g. number of dairy cows and milk yield). These factors together create complex dynamics in the global milk market, affecting both supply and demand and consequently also affecting countries' exports and imports (Bai et al., 2023).

Figure 2
Comparison of fresh milk import and export (2023)



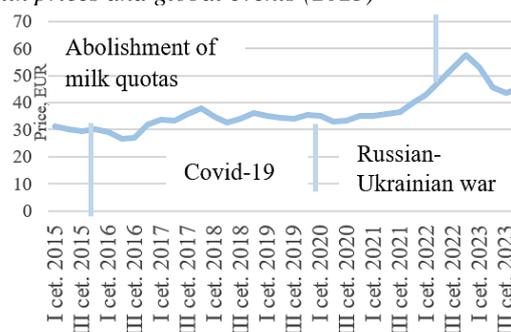
The dairy sector plays a significant role in the food industry; the export of dairy products also plays an essential role in the overall agricultural and food trade of almost all European countries, as well as in the global dairy trade (Bojnec & Ferto, 2014). The imbalance between milk demand and supply in the world creates new export opportunities, especially for the countries with a developed dairy industry. In contrast, countries where demand for dairy products exceeds local production are dependent on imports (Kondaridze & Luckstead, 2023).

Figure 2 shows the distribution of fresh milk imports and exports in different European countries, which provides an insight into the trade flows of milk. This comparison allows to identify which countries are mainly milk importers and which are exporters. For example, countries such as Germany, Poland and France are exporting countries, while Ireland and Bulgaria are importing countries. Countries with higher imports than exports show a greater dependence on external markets, while countries where exports exceed imports demonstrate an export orientation and a lower dependence on external markets. In general, countries with a developed dairy production infrastructure are the main exporters, while countries

with less developed domestic production rely on imports to meet domestic demand.

As mentioned earlier in this article, the dairy market is subject to external factors and for this reason, milk prices also change, influenced by various global events. As mentioned earlier in this article, the dairy market is subject to external factors and for this reason, milk prices also change, influenced by various global events. Figure 3 shows milk prices in Europe from 2015 to 2023, and global events such as the end of milk quotas, Covid-19 and the Russian-Ukrainian war that have affected prices in the sector.

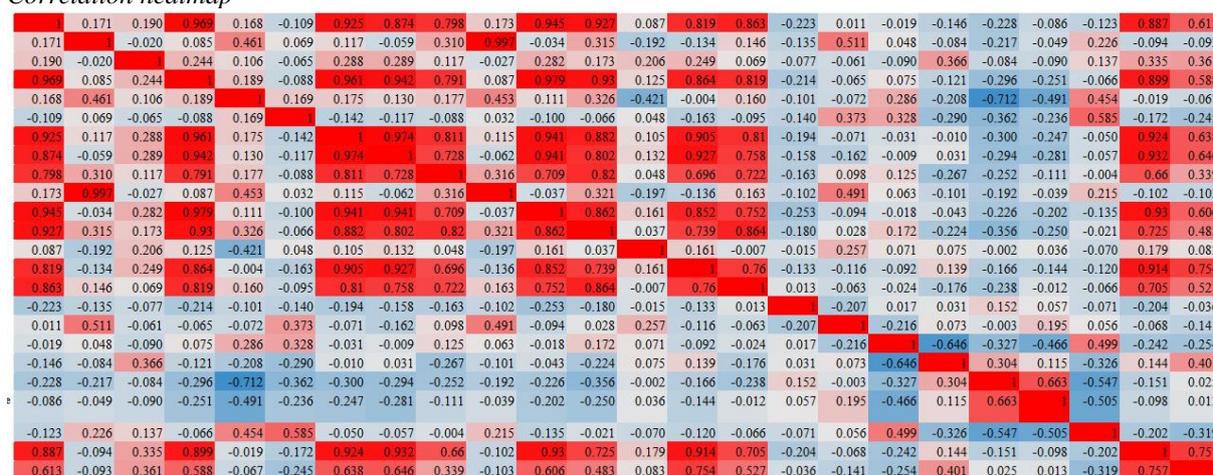
Figure 3
Milk prices and global events (2023)



One of the recent events that significantly affected milk prices is the Russia-Ukraine war, which began in 2022. The war disrupted production and supply chains, leading to significant increases in fertilizer and energy prices, which increased the costs of milk processing, which in turn was reflected in higher dairy product prices. Export and import restrictions also significantly affected dairy prices, as countries were forced to review their trading partners (Hassen & Bilali, 2022). To carry out the cluster analysis, first the factor analysis was done and complex factors were made.

For measuring sampling adequacy the Kaiser–Meyer–Olkin (KMO) test and Bartlett’s test of sphericity was taken into account to proceed to factor analysis. The result of the KMO =0.632 > 0.5, meaning that the sample is adequate. Bartlett’s test result shows a p-value (Sig.) of 0.000, which is less than 0.05, indicating that the variances are significantly different. To optimise the results, a correlation analysis was carried out and the indicators with weak mutual correlation were excluded from further analysis. A correlation matrix visually represents the relationships between different variables, Figure 4.

Figure 4
Correlation heatmap



A positive correlation (red color) indicates a strong relationship between two variables, a negative correlation (blue color) indicates an inverse relationship between the variables, and gray color indicates that there is no significant correlation. For identifying the number of factors, the extraction method of the principal component analysis and the

Kaiser criterion were used, which allowed the identification of indicators that constitute three complex factors. The Rotated Component Matrix (Table 2) presents the results of this analysis, highlighting the relationship between the main indicators and their factors.

Table 2
Rotated component matrix

Indicators	F1	F2	F3
Number of dairy cows	0.959	0.006	0.169
Collection of cow's milk	0.972	0.136	0.052
GDP per capita	0.097	0.677	0.440
Milk treated-distribution	0.976	0.104	0.069
Compensation of employees	0.959	0.131	-0.117
Fresh milk export	0.789	0.092	0.325
Fresh milk import	0.025	0.100	0.976
Production of cheese	0.960	0.061	-0.065
Production of butter	0.886	0.190	0.306
Production of acidified milk	0.933	-0.012	-0.178
Skimmed milk powder	0.849	0.002	0.189
Population change	-0.162	0.778	0.131
Population	0.951	-0.097	-0.138
Employment rate	-0.071	0.687	-0.009
Share of GV, agriculture	-0.222	-0.816	-0.135
Share of employment, agriculture	-0.148	-0.838	0.113
Area	0.711	-0.245	-0.153
Selling prices of milk	0.025	0.110	0.972

The extraction method was the Principal Component Analysis and the rotation method was Varimax with Kaiser normalization.

Rotated Component Matrix analysis shows how dairy sector indicators are related to three identified factors. Based on the indicators, F1 could be labelled **Dairy production** and includes the following indicators: number of dairy cows (0.959), collection of cow's milk (0.972), milk treated-distribution (0.976), compensation of employees (0.959), production of cheese (0.960), production of butter (0.886), production of acidified milk

(0.933), and skimmed milk powder (0.8495). All factors are positively correlated with F1. F2 could be labelled **Market**, which is positively correlated with GDP per capita (0.6771) and population change (0.778).

Macroeconomic Environment, which is positively correlated with fresh milk import (0.976) and selling prices of milk (0.972).

Cluster analysis was performed based on the factor analysis. ANOVA results indicate that all factors are significant for cluster analysis (Table 3) with Sig. < 0.05.

Table 3
ANOVA

	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
REGR factor score 1 (Dairy production)	4.451	5	.178	21	24.940	.000
REGR factor score 2 (Market)	4.501	5	.166	21	27.035	.000
REGR factor score 3 (Macroeconomic Environment)	5.034	5	.039	21	127.685	.000

The Europe countries were grouped into 6 clusters. The number of clusters was determined based on the Elbow rule. Cluster 3 consists of a larger number of countries – 11 and represents countries with well-developed dairy production, but with challenges in market development and macroeconomic environment. The cluster centres (Table 4)

illustrate the key characteristics of the identified clusters. Based on the cluster analysis of the dairy sector, the country closest to the Cluster 3 centre is Finland, while Belgium is the furthest from the cluster centre. Countries in this cluster have moderately developed market, but they have weaker milk production.

Table 4
Final Cluster Centres

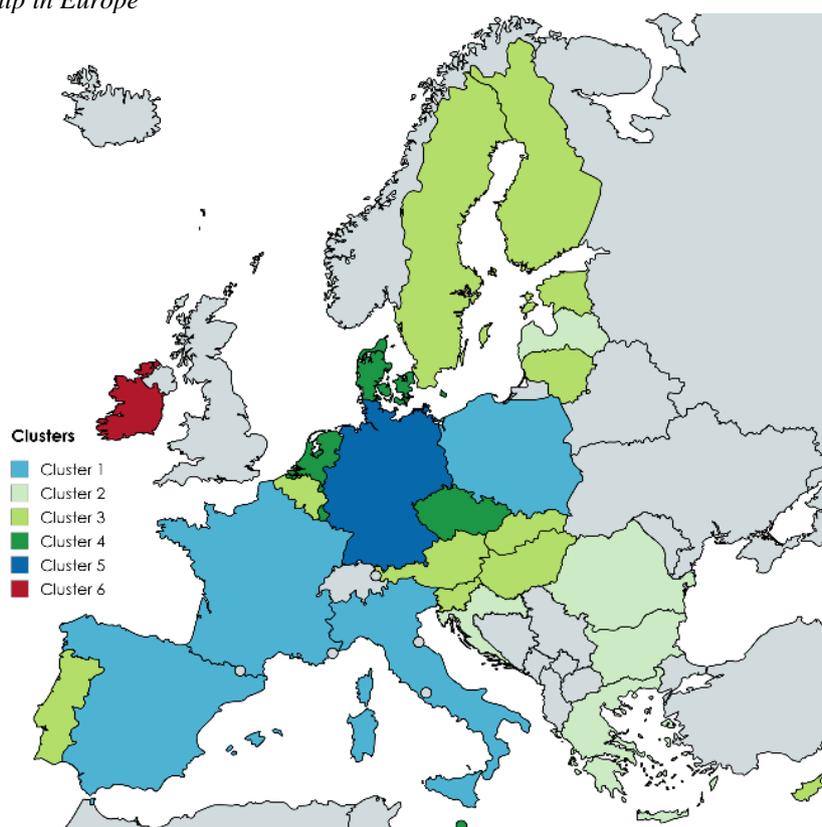
	Cluster					
	1	2	3	4	5	6
REGR factor score Dairy production	1.30707	-.42551	-0.43863	-0.36611	3.42190	0.13288
REGR factor score Market	-0.56052	-1.53199	0.19556	1.26530	0.90221	0.52220
REGR factor score Macroeconomic Environment	-0.29574	0.05319	-0.24288	-0.21530	-0.22136	4.88655

Countries in clusters 1, 5 and 6 have relatively well-developed dairy production. Moreover, the country in cluster 6 has stronger macroeconomic indicators. There is 1 country in cluster 6 - Ireland, which is a typical representative country of this cluster. Cluster 5 also has only 1 country - Germany, which is a typical representative country of this cluster, with well-developed dairy production and a moderately developed market. Cluster 4 has 5 countries, with Denmark closest to the centre. This cluster represents countries with a well-developed market, but with weak dairy production. Macroeconomic indicators are also relatively low in this cluster. And finally, cluster 2 has 5 countries, with Bulgaria closest to the centre. The countries in this cluster have the weakest dairy production and the least developed market, making them the most vulnerable group. The mapping (Figure 5) of the cluster membership allows us to distinguish four characteristic regions: Mediterranean and Central

European countries with medium production and market levels, Eastern European and Balkan countries with weaker indicators in production and market, Nordic and Western European countries with moderately developed milk production and a moderately developed market, and Central European countries with moderately developed dairy production countries with a well-developed market while Germany and Ireland are typical representative countries of their cluster.

Overall, this shows that regional differences in the dairy sector of European countries are significant. Figure 5 shows an interesting trend in which the Baltic states are not in the same cluster - Estonia and Lithuania are in cluster 3, while Latvia is in cluster 2. This indicates that Lithuania and Estonia are in the same cluster as countries with well-developed dairy production, but Latvia is in the cluster with weakest dairy production.

Figure 5
Cluster membership in Europe



As Poland is one of the largest milk producers in Europe and, according to the EU Agricultural Outlook 2024-2035, has the potential to continue the growth trend in milk production (Agricultural outlook, 2024; Parzonko & Bórawski, 2020), it is in Cluster 1. Latvia, which is not in the same cluster as Estonia and Lithuania, has the opportunity to improve its dairy sector (improving market competitiveness and increasing milk productivity) and join Cluster 1.

Conclusions

1. In major European countries (including the Baltics countries), milk yield is higher than the number of cows being milked. This trend may indicate an improvement in the efficiency of the industry, for example, by farmers selecting cows with the highest genetic potential, which can produce more milk during lactation.

2. Global events, including abolishment of milk quotas, the COVID-19 pandemic and the Russia-Ukraine war, have had a significant impact on milk prices and trade model. This has resulted in disruptions in supply chains, rising raw material and energy costs and changes in trade relations. This shows that the dairy sector is at risk of crises.

References

Arendok, J. M. & Liinamo, A. E. (2003). Dairy cattle production in Europe. *Theriogenology journal*, 59(2), 563-569. [https://doi.org/10.1016/S0093-691X\(02\)01240-2](https://doi.org/10.1016/S0093-691X(02)01240-2)

3. Cluster analysis allowed dividing European countries into 6 clusters, which shows that regional differences in the dairy sector of European countries are significant. The weaker indicators in dairy production are in Eastern European and Balkan countries, but Mediterranean, Central European, Nordic and Western European countries are with medium dairy production. Germany and Ireland are typical representative countries of their cluster with well-developed dairy production.

4. The fact that the dairy sector differs among European countries is also visible among the Baltic countries, where Latvia is not in the same cluster as Lithuania and Estonia. Considering that Poland is one of the largest milk producers in Europe and is in a more competitive cluster, Latvia should aim to join this cluster. By adopting best practices from Poland, Latvia could strengthen its dairy sector and achieve greater competitiveness in the European market.

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- Berry, D. P., Buckley, F., Dillon, P., Evans, R. D., Rath, M., & Veerkamp, R. F. (2003). Genetic Relationships among Body Condition Score, Body Weight, Milk Yield, and Fertility in Dairy Cows. *Journal of Dairy Science* 86(6), 2193-2204. [https://doi.org/10.3168/jds.S0022-0302\(03\)73809-0](https://doi.org/10.3168/jds.S0022-0302(03)73809-0)
- Bojnec, Š. & Feto, I. (2014). Export competitiveness of dairy products on global markets: The case of the European Union countries. *Journal of Dairy Science*, 97(10), 6151-6163. <https://doi.org/10.3168/jds.2013-7711>
- Bai, Z., Liu, C., Wang, H., & Li, C. (2023). Evolution Characteristics and Influencing Factors of Global Dairy Trade. *Sustainability*, 5(2), 931-951. <https://doi.org/10.3390/su15020931>
- Bórawska, B. A., Bórawski, P., Guth, M., Parzonko, A., Rokicki, T., Klepacki, B., ..., & Dunn, J. W. (2021). Price changes of dairy products in the European Union. *Agricultural Economics*, 67(9), 373-381. <https://doi.org/10.17221/61/2021-AGRICECON>
- European Commission. (2024). *EU Agricultural Outlook 2024-2035*. European Union. https://agriculture.ec.europa.eu/document/download/48b04248-de6c-4608-bbcf-f2c9e0ed9d2b_en?filename=agricultural-outlook-2024-report_en.pdf
- Hansen, L. B. (2000). Consequences of Selection for Milk Yield from a Geneticist's Viewpoint. *Journal of Dairy Science*, 83(5), 1145-1150. [https://doi.org/10.3168/jds.S0022-0302\(00\)74980-0](https://doi.org/10.3168/jds.S0022-0302(00)74980-0)
- Hassen, T. B. & Bilali, H. E. (2022). Impacts of the Russia-Ukraine War on Global Food Security: Towards More Sustainable and Resilient Food Systems? *Foods*, 11(15). <https://doi.org/10.3390/foods11152301>
- Kondaridze, M. & Luckstead J. (2023). Determinants of dairy-product trade: Do subsidies matter? *Journal of Agricultural Economics*, 74(3), 857-873. <https://doi.org/10.1111/1477-9552.12536>
- Knips, V. (2005). Developing Countries and the Global Dairy Sector Part I Global Overview. *Food and Agriculture Organization of the United Nations*. <https://doi-org/10.22004/ag.econ.23768>
- Neethirajan, S. & Kemp, B. (2021). Digital Livestock Farming. *Sensing and Bio-Sensing Research*, 32. <https://doi.org/10.1016/j.sbsr.2021.100408>
- OpenAI. (2025). *ChatGPT* (Mar 16 version) [Large language model]. <https://chat.openai.com>
- Otte, J. & Chilonda, P. (2006). *Indicators to monitor trends in livestock production at national, regional and international levels*. *Livestock Information, Sector Analysis and Policy Branch, Animal Production and Health Division*. Food and Agriculture Organisation, Vialle delle Terme di Caracalla, 00100 Rome, Italy.
- Popescu, A., Stoian, E., & Serban, V. (2019). The EU-28 milk sector trends in the period 2009-2018. *Economic Engineering in Agriculture and Rural Development*, 19(4), 249-264. https://managementjournal.usamv.ro/pdf/vol.19_4/Art36.pdf
- Pappa, I., Illiopoulos, C., & Massouras, T. (2019). On Sustainability of a Dairy Sector in Crisis. *International Journal on Food System Dynamics*, 10(2), 130-150. <https://doi.org/10.22004/ag.econ.345314>
- Parzonko, A. & Bórawski, A. (2020). Competitiveness of Polish dairy farms in the European Union. *Agricultural Economic*, 66(4), 168-174. <https://doi.org/10.17221/254/2019-AGRICECON>
- Rytkönen, P., Hernandez, L. A. G., & Jonsson, U. (2020). *From local champions to global players. Essays on the history of the dairy sector*. Universitatis Stockholmiensis. <https://www.diva-portal.org/smash/get/diva2:664915/FULLTEXT01.pdf>
- Viira, A. H., Omel, R., Värnik, H., Luik, H., Maasing, B., & Põldaru, R. (2015). Competitiveness of the Estonian dairy sector, 1994–2014. *Journal of Agricultural Science* 2 * XXVI * 2015, 84-105. https://www.researchgate.net/publication/287982280_Competitiveness_of_the_Estonian_dairy_sector_1994-2014#fullTextFileContent
- www.ec.europa.eu. (2023). *www.ec.europa.eu*. Retrieved March 2, 2025, from <https://ec.europa.eu/eurostat/web/main/data/database>