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APPLYING CLUSTER ANALYSIS IN THE BULGARIAN CHEMICAL INDUSTRY FOR THE PERIOD 2010–2020

Velimira Stoyanova[1]*, *Aleksandra Ravnachka*[1], *Stefan Genchev*[1]

[1]National Institute of Geophysics, Geodesy, and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria; e-mails: stoyanovavelimira@gmail.com; a_lravnachka@abv.bg; st.genchev85@abv.bg

Abstract: This paper discusses the territorial organization of the chemical industry in Bulgaria. Using the ESRI ArcGIS software and applying cluster analysis, the study aims to group (cluster) the 28 Bulgarian districts (NUTS 3 level classification) based on produced output, persons employed, and Bulgarian lev (BGN) equivalent of foreign exchange earnings from exports for the period 2010–2020. Three reference years, 2010, 2015, and 2020, have been selected for the observed period. The general conclusion is that the chemical industry in Bulgaria is characterized by high territorial concentration. Varna was the leading district in developing the chemical industry in the observed period from 2010 to 2020, followed by Plovdiv, Ruse, and Sofia (the capital). At the other pole were the districts of Vidin, Montana, Vratsa, Pleven, Lovech, Razgrad, Silistra, Targoviste, Dobrich, Pernik, Kyustendil, Blagoevgrad, Sliven, Yambol, and Kardzhali. The findings of the research show that territorial polarization is linked with several factors that can be grouped according to their impact into four groups: 1) raw material and energy, 2) transport infrastructure and proximity to the end user, 3) state and environmental regulations, and 4) provision of skilled labor.

Keywords: K-means clustering; Geographic Information Systems (GIS); chemical industry; organic and inorganic chemistry; Bulgaria

1. Introduction

During the last decades of the 20th century and from the beginning of the 21st century, the chemical industry asserted itself as a leading economic activity—both in the production of goods and by providing employment. Worldwide, chemical product use is increasing, and "chemicals are needed for more than 95% of the world's manufactured goods" (Viver Gargallo, 2023, p. 2). The main producers of chemical substances and products are enterprises from China, the United States of America, Switzerland, Japan, Singapore, Russia, the countries of the European Union (EU), Great Britain, etc. Production growth is also strong in other countries such as India, Brazil, South Africa, and Indonesia, which are predicted to have an increasing share of the chemical trade (Boyanov, 2020). An important part of the

*Corresponding author, e-mail: stoyanovavelimira@gmail.com

economic development of the EU member states has been and continues to be the chemical industry. In the EU, chemical industry is concentrated in six member states: Germany, France, Italy, the Netherlands, Belgium, and Spain (Boyanov, 2020). Most of the worldwide leading manufacturers of the industry originated from these countries, and among them are BASF (Germany), LyndellBasell (Netherlands), AirLiquide (France), Evonik Industries (Germany), Covestro (Germany), Bayer (Germany), Solvay (Belgium), DSM (Netherlands), and Borealis (Austria) (Boyanov, 2020; Tullo, 2018). According to the European Chemical Industry Council (Ivanova, 2023), Bulgaria was 19th among EU countries in 2020 sales of chemicals, with a value of 1.6 billion euros.

The first chemical plants producing concrete were built during the Industrial Revolution in Europe. Since then, this industry is constantly developing. Many modern products use chemicals. In the 1960s, the globalization of this industry began when many companies based in different countries invested and built plants in many parts of the world (American Chemistry Council, 2019). World economic growth, policies that support industrial development and competitiveness, and advances in technology, logistics, and distribution of goods from the industry are among the main reasons that led to the globalization of this industrial sector (American Chemistry Council, 2019; Boyanov, 2020).

The chemical industry is also vital for the economy of Bulgaria. It produces an ever-increasing variety of chemicals and products, which are raw materials for numerous products and goods used by society. Its importance is also determined by export orientation (Dimitrov, 2002). Production activities in the chemical industry significantly impact the environment by polluting valuable water resources and soils, and by the discharge of harmful gases and chemicals in the atmosphere. This, in turn, leads to several restrictive measures and requirements for production activities, affecting the companies' costs and competitiveness in the sector (Dimitrov, 2002). The country's chemical industry takes one of the first places according to several indicators in the national economy. In 2020, 634 enterprises and companies operating in the country in which 14,415 people (0.43% of the labor force in Bulgaria) are employed in the production of chemical products (National Statistical Institute of Bulgaria [NSI], 2022). The production of soda ash, fertilizers, and other products represents a significant share of the country's exports.

The dynamics of the production volume in Bulgaria's chemical industry follow the economic situation and local and global trends. There are three distinguishable periods of development, delineated by changes in the business cycle:

1. Before 2009, the integration processes and the country's accession to the EU were related to the effective restructuring of the economy and the institutional environment. The economic policies conducted, including those financed under operational programs, positively improved the business climate in the country (Ravnachka, 2021), leading to favorable trends in the dynamics of chemical industry development.
2. The 2007–2008 global financial crises affected the Bulgarian economy with delay when a decline in all economic activities was observed from 2009 to 2014. What follows is a relatively long and slow recovery period.
3. After 2014, the economic situation in the country changed for the better. Economic growth is increasing, which has a positive impact on the development of the chemical industry. The pace of economic development has (to some extent) been (temporarily) suspended with the onset of the COVID-19 crisis in 2020. Additionally, the industry's

significant problems relate to the lack of well-trained personnel, an aging workforce, and inadequate links between universities and industry.

This study aims to group (cluster) the 28 districts at the third-level of Nomenclature of Territorial Units for Statistics (NUTS 3) in Bulgaria. It is based on produced output, persons employed, and BGN equivalent of foreign exchange earnings from exports for the period 2010–2020.

2. Literature review

A great interest in cluster analysis, including in the grouping of economic data in science, was observed after 1960, when the number of software programs used for cluster analysis grew rapidly. Due to this fact, the number of published articles using this method in various scientific disciplines is rapidly increasing (Akkucuk, 2011; Blashfield & Aldenderfer, 1978; Duran & Odell, 1974; Gáll & Michálková, 2023; Kettenring, 2006; Kronthaler, 2005; Manrai et al., 2001; Nikolova, 2020; Nogueira & Madaleno, 2021). Nowadays, Geographic Information Systems (GIS) are applied in all the spheres of public life and have numerous applications in various fields, such as agriculture, urban planning, traffic, transport, security, public services, public administration, business, and scientific research. In Bulgaria, during the last decade, GIS has been increasingly used in various fields of geographic research, assessing problems in the ecosystem and landscape studies (Borisova et al., 2023; Chilikova-Lubomirova et al., 2022; Nedkov et al., 2021; Prodanova, 2021; Prodanova & Varadzhakova, 2022; Stefanov et al., 2023), climate changes (Asa & Zemba, 2023; Belev et al., 2023), tourism (Cholakova & Dogramadjieva, 2023), demography (Kazakov, 2014, 2015; Mikova, 2019; Traykov & Tsvetkov, 2021), and settlements (Nekova et al., 2023), while a cluster analysis performed with the ArcGIS software was applied to investigate the light and food industry (Ravnachka & Stoyanova, 2022a, 2022b).

However, there are very few articles devoted to the importance of the chemical industry in the country’s economy. Boyanov (2019) presents the impact of the EU's environmental policy on the international competitiveness of economic entities from the chemical industry in Bulgaria. Boyanov (2020) analyzes the current state of the chemical industry in the EU and highlights the main challenges it must deal with in the upcoming years. Lyubenova and Kirova (2024) identify the risks in the Bulgarian chemical industry that most need to be managed through an innovation management approach.

Scientific publications on the chemical industry worldwide cover topics such as circular economy, globalization, environmental pollution, etc. Kathuria et al. (2008) examine the differences in domestic and international growth strategies of manufacturing and service firms in the chemical industries. Shi and Zeng (2014) study the application of K-means clustering to environmental risk zoning of chemical industrial areas. Zhang et al. (2019) study the driving factors and predictions of CO_2 emission in China's coal chemical industry. Abedsoltan (2023) discusses the impacts and challenges, as well as opportunities that COVID-19 brought to the chemical industry. Wangthong and Rojniruttikul (2023) analyze the confirmatory factor of the model of factors influencing the sustainability of the chemical industry in Thailand. Kruglova (2023) presents the problem of import substitution in the chemical industry and its impact on other sectors of the economy. Wang (2023) analyzes China's chemical industry from the circular economy perspective, which will elaborate on the reasons for applying circular economy policies in this industry. Schultz et al. (2023) study stakeholder management to facilitate collaboration for a systemic transition to a circular economy. Yang et al. (2024) consider the coal chemical industry, as a carbon-intensive industry in China. Dehiya (2024) presents the chemical industry as an exhaustive consumer of resources and a generator of a significant amount of waste. Nyirenda and Malabo (2024) in their article present mineral and bioresource exploitation for the transformation and sustainability of the chemical industry in Zambia.

3. Materials and methods

3.1. Study area

Bulgaria is located in Southeastern Europe, occupying a central place in the territory of the Balkan Peninsula. In administrative terms, it is divided into two statistical zones—NUTS 1 (1. North and South-Eastern Bulgaria and 2. Southwest and South-Central Bulgaria), six statistical regions—NUTS 2 (1. Northwest, 2. North Central, 3. Northeast, 4. Southwest, 5. South Central, and 6. Southeast), and 28 districts—NUTS 3 (Figure 1).

Figure 1. Study area.

Since January 1, 2007, Bulgaria has been a member of the EU. On February 20, 2008, based on Regulation (EC) No. 176/2008 of the European Parliament and of the Council amending the annexes to Regulation No. 1059/2003, in force since May 26, 2003, Bulgaria was divided into territorial units for statistical purposes (NUTS). Regulation No. 1059/2003 is to create a common statistical classification of territorial units to enable the collection, compilation, and dissemination of harmonized regional statistics in the European Union (NSI, n.d.). The classification of territorial units for statistical purposes in Bulgaria has been in force since February 14, 2009.

The initial establishment of the chemical industry in the lands populated with Bulgarian people can be traced back to the period of Ottoman rule when the production of gunpowder and saltpeter began in Pazardzhik and Razgrad. In 1878, the first small factories for soap, wax, and alcohol were built in Gabrovo and Veliko Tarnovo. After the Liberation, the number of chemical enterprises in the country increased. The factories for alcohol (Sofia's Kniyazhevo district), inks and pencils (Burgas), explosives (Shumen), soap (Ruse and Plovdiv), paints, varnishes, and medicines (Sofia), and vegetable oils (Kostinbrod) were established. In 1929, the first oil refining enterprise was opened in Ruse. It processed oil from Romania and produced fuel oil, gasoline, and oil-based lubricants. The number of enterprises from the considered period grew significantly, and by 1944 Western European companies such as I. G. Fabenindustri from Germany and Solvay from Belgium, began to operate in Bulgaria (Dimitrov, 2002).

In the period after the Second World War, significant changes took place in the economy and the chemical industry. Nationalization was carried out and the number of enterprises initially decreased. Subsequently, the beginning of a more modern chemical industry was established. In Dimitrovgrad, Stara Zagora, and Devnya, large enterprises are being built, producing fertilizers, and soda.

The construction of the Petrochemical Combine near Burgas in the early 1960s established the beginning of the modern petrochemical industry in the country. Organic chemistry was gaining more and more importance. During the 1970s and 1980s, further transformations occurred within the industrial sector. Several chemical enterprises began functioning in smaller towns such as Gotse Delchev, Parvomai, Tervel, Kula, etc. (Dimitrov, 2002). The economic crisis in the country which began in the late 1980s, accompanied by the change of the socio-economic system after 1990, impacted all economic activities, including chemical production. After 2000, the economic situation in the country stabilized, and a growth in chemical production was reported (Dimitrov, 2002). In 2010, the production was worth €960,494 thousand (BGN 1,878,563 thousand), and in 2020, it was €1,599,245 thousand (BGN 3,127,852 thousand) (NSI, 2022). In 2022, the chemical industry reached approximately 45% growth in exports, which was €3.7 billion (BGN 7.2 billion) in monetary terms (Eurostat Statistics Explained, 2023). The modern sectoral structure of the chemical industry is presented in Figure 2.

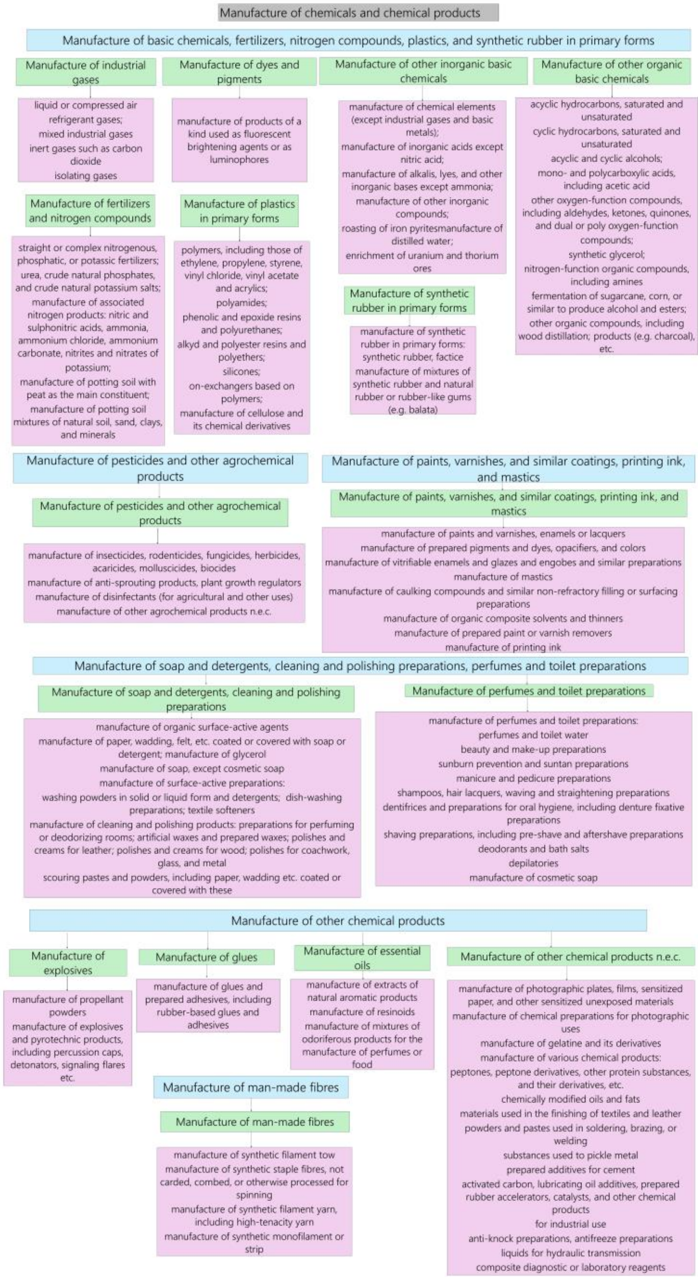

Figure 2. Branch structure of the chemical industry.
Note. The authors made the graph based on the data from "*NACE Rev. 2 Statistical classification of economic activities in the European Community*", Eurostat, 2008.
https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF

3.2. Research data

The research used data from the National Statistical Institute of Bulgaria on the production of chemical products (excluding the production of medicinal substances and products). For the grouping of the districts, data on three variables (produced output, persons employed, and BGN equivalent of foreign exchange earnings from exports) for 2010, 2015, and 2020 were used.

To reveal the spatial differences, the Ministry of Environment and Water database was developed under the project "The Study on Integrated Water Management in the Republic of Bulgaria" and implemented by the Japanese Agency for International Cooperation (2008). It includes data on the following layers: settlements, districts with their adjacent borders, the state border, etc. The entire database used to compile the maps is in the Universal Transverse Mercator (UTM) coordinate system with the World Geodetic System 1984 (WGS84), zone 35.

3.3. Research methods

The entire clustering process for the chemical industry is shown in Figure 3. The grouping of the regions in Bulgaria according to the selected indicators was carried out with the software ArcGIS® Desktop, ArcMap version 10.6.1 (ESRI) with the Arc Toolbox. The "No_Spatial_Constraint" option was selected for the Spatial Constraints parameter and the "Find_Seed_Locations" option for the Initialization Method.

The K-means algorithm was applied to partition features into groups. The algorithm performs optimal data partitioning by minimizing the sum of the squared error (SSE) criterion. Due to its ease of implementation, the K-means algorithm is regarded as one of the most valuable clustering methods (Hamfelt et al., 2011). However, it suffers from several major drawbacks. One is that the iterative procedure cannot guarantee the convergence to a global optimum, although the convergence of K-means was proved. Another analysis problem is the number of clusters involved in the process—the operator must know the exact number in advance. Following the above, a very important topic in cluster analysis is identifying the number of clusters (Hamfelt et al., 2011).

Figure 3. Flow diagram of the study.

4. Results

Figures 4, 5, and 6 show graphs of the variables used to group output, employees, and foreign exchange earnings from exports in Bulgaria's chemical industry by districts (NUTS 3) from 2010 to 2020.

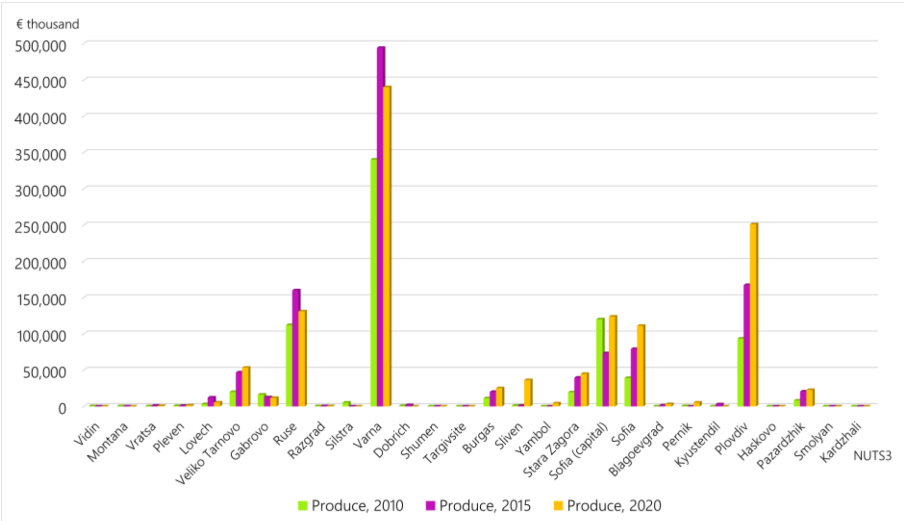

Figure 4. Manufactured products of the chemical industry in Bulgaria by districts (NUTS 3).

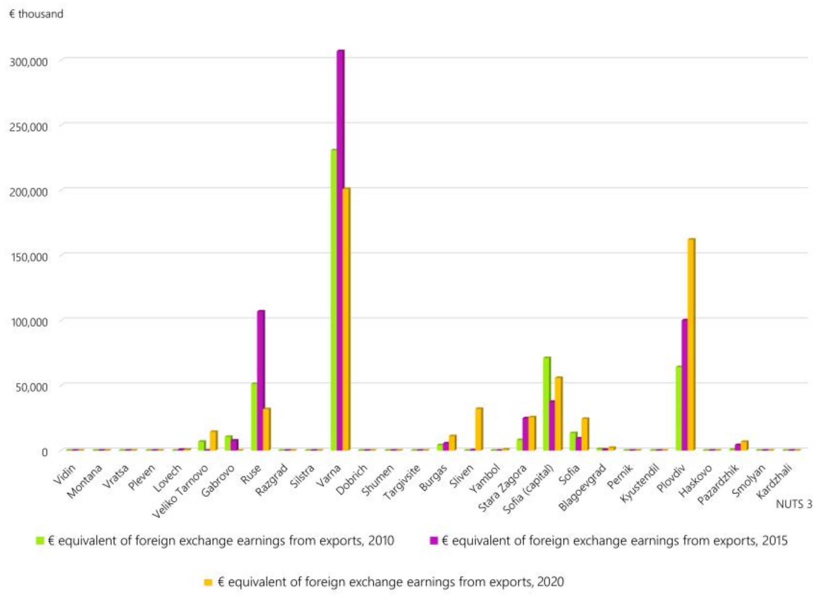

Figure 5. Foreign exchange earnings from exports in the chemical industry in Bulgaria by districts (NUTS 3).

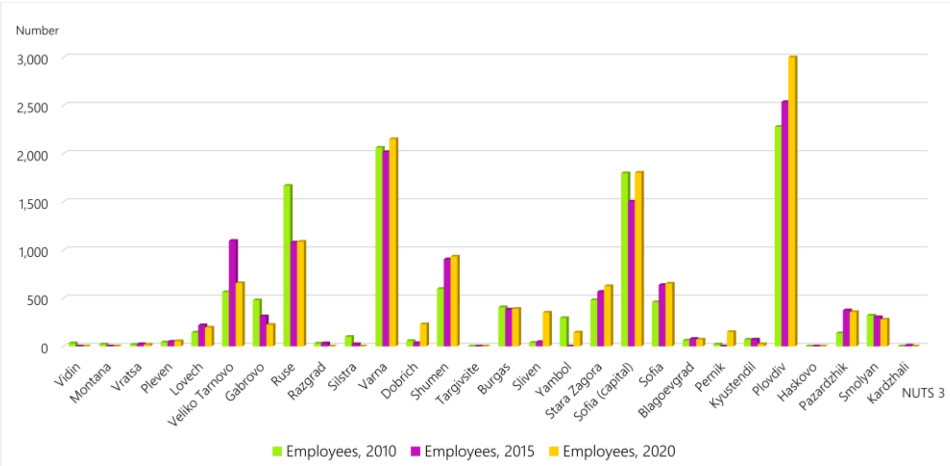

Figure 6. Employed in the chemical industry in Bulgaria by district (NUTS 3).

The evaluation of the selected variables is presented in Table 1. The coefficient of determination (R^2) is equal to or close to 1 (100%). The percentage calculated by the Grouping Analysis is very high, indicating that the selected variables greatly influence the clustering of the areas. The R^2 coefficient is the highest for foreign exchange earnings from exports.

Table 1. Statistical variables and indicators

Year	Statistical indicators	Variable		
		Foreign exchange earnings from exports	Produced output	Employed persons
2010	Mean	32,296.4	55,503.5	434.4
	Std. Dev.	88,893.3	134,188.9	652.8
	Min	0	0	0
	Max	451,333.0	665,577.0	2,279.0
	R^2	0.9999	0.9998	0.9995
2015	Mean	42,267.5	79,280.2	438.8
	Std. Dev.	119,681.9	191,451.9	649.5
	Min	0	0	0
	Max	600,367.0	966,449.0	2,537.0
	R^2	1	0.99996	0.9999
2020	Mean	88,792.5	39,742.4	478.4
	Std. Dev.	185,284.8	91,990.6	719.2
	Min	0	0	0
	Max	860627.0	393168.0	3008.0
	R^2	1	0.9998	0.9997

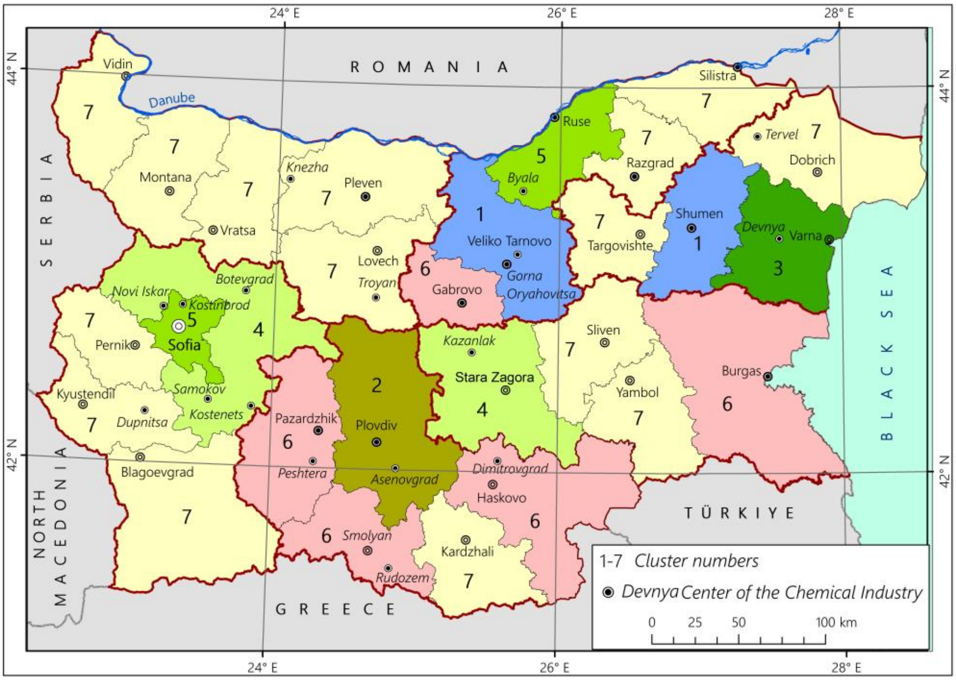

Figure 7. Clusters of the chemical industry for 2010–2020.

Figure 7 shows clusters for the period 2010–2020 in the chemical industry. Cluster 1 includes the regions of Veliko Tarnovo (North-Central Region) and Shumen (North-Eastern Region) (Figure 7). They are characterized by income from foreign exchange earnings from exports €3,541 thousand (BGN 6,947 thousand), the output of €20,021 thousand (BGN 39,281.2 thousand), and 791 people employed in the sector (Figures 4, 5, and 6).

Cluster 4 includes the districts of Sofia (Southwest Region) and Stara Zagora (Southeast Region) (Figure 7). For the period 2010–2020, they are characterized by income from foreign exchange earnings from exports of €17,650 thousand (BGN 34,629 thousand), the production is €55,574 thousand (BGN 109,036 thousand), and the number of people employed in sector 570 (Figures 4, 5, and 6).

Cluster 6 includes the districts of Gabrovo (North-Central Region), Pazardzhik, Smolyan, Haskovo (South-Central Region), and Burgas (South-Eastern Region) (Figure 7). They are characterized by income from foreign exchange earnings from exports of €3,396 thousand (BGN 6,662.95 thousand), the output of €9,889 thousand (BGN 19,402.22 thousand), and the 264 employed in the sector (Figures 4, 5, and 6).

The least developed areas of the chemical industry are included in Cluster 7. It consists of fifteen districts: Vidin, Montana, Vratsa, Pleven, and Lovech (Northwest Region), Razgrad and Silistra (North-Central Region), Targoviste (Northeast Region), Pernik, Kyustendil, and Blagoevgrad (South-West), Kardzhali (South-Central Region), Sliven and Yambol (South Region) (Figure 7). They are characterized by zero foreign currency earnings from exports, the production is €186–462 thousand (BGN 364–904 thousand), and the employed persons in the sector are between 16–32 people (Figures 4, 5, and 6).

According to the results, the best economic indicator is the district of Varna, Cluster 3 (Northeastern Region); Plovdiv, Cluster 2 (South-Central Region); Ruse (North-Central Region), and Sofia (capital) (South-West Region), Cluster 5. During the considered period 2010–2020, in the Varna district (Cluster 3), the production varied between €340,304 and 494,137 thousand, the euro equivalent of foreign currency earnings from exports varies from 201,023 to 306,962 thousand, and the employed persons in the sector are between 2,016 and 2,151 people (Figures 4, 5, and 6). Cluster 2 (Plovdiv) is characterized by income from foreign exchange earnings from exports between €64,218 and 162,127 thousand, the output between €93,482 and 2,510,245 thousand, and the number of people employed in the sector between 2,279 and 3,008 (Figures 4, 5, and 6).

5. Discussion

The findings of this research align with previous study (Knauff, 1973) showing that regions are leading in the structure of the chemical industry in Bulgaria due to the following factors: communal services, availability of raw materials, costs, and time for transporting the finished products to the customers, wastewater disposal, and availability of labor and specialized personnel. These factors could be supplemented and combined according to their impact into four separate groups: 1) raw material and energy, 2) transport infrastructure and proximity to the end user, 3) state and environmental regulations, and 4) provision of skilled labor. Below, we elaborate on the influence of each group of factors on the location and structure of the chemical industry in Bulgaria during the observed period.

5.1. Raw material and energy factors

Chemical industry productions consume many raw materials, such as oil and natural gas, mineral raw materials, etc. An important condition is the continuous raw material supply process (Dimitrov, 2002). With few exceptions, similar production facilities are located near the deposits from which the raw materials are extracted. An example in this regard is Cluster 3 (Varna) with the soda ash plant of Solvay located near the town of Devnya, Agropolyhim Joint-Stock Company (JSC) located near the port of Varna-Zapad, and the deposits of rock salt, limestone, and water. For organic chemistry, although Bulgaria does not have deposits of oil and natural gas, a good example regarding the transport availability of raw materials is the oil refining combine Lukoil-Neftohim in the city of Burgas (Cluster 6), which is supplied with raw materials by using a specially built oil-unloading port (Rosenets).

5.2. Transport infrastructure and proximity to the end user

Transport infrastructure is an important factor in most industrial productions, not only from the point of view of the supply of raw materials, but also the transportation of finished products to consumers (Dimitrov, 2002). Most of the products produced in the chemical industry are directly oriented to the end user, which implies that most enterprises of the branch are located near the relevant markets or transport hubs. The examples are Cluster 4 (Sofia district), Cluster 2 (Plovdiv), and Cluster 5 (Sofia–capital). Leading enterprises in the Cluster 5 (Sofia–capital) and Cluster 4 (Sofia district) are Himatech JSC (Sofia) and Aurubis

Bulgaria (Pirdop). Himatech JSC (successor to the Central Institute of Chemical Industry, transformed in 1991) produces chemicals for cleaning and degreasing metal surfaces, auto-cosmetic products under the Avtoefektol brand, chemical fibers, and textile auxiliaries (washers, wetting agents, dyeing and printing, as well as softeners), synthetic resins, plant protection products, electrical insulating varnishes, and others. Aurubis Bulgaria produces sulfuric acid (technical and for batteries). In Sofia (the capital), Lakprom JSC produces paints, varnishes, primers, adhesives, anti-corrosion systems, and metal, concrete, wood protection, etc. Production of paints and varnishes in the Sofia region takes place in Novi Iskar and Kostinbrod (Emailchim JSC). Emailchim JSC produces primers, varnishes, enamel varnishes, paints, silver ferrite, anti-corrosion systems for metal, decorative self-leveling floors, self-leveling floors and systems, industrial floor coverings, Espol—self-leveling composite floor material, fire-resistant varnishes for floor coverings, Glasflake systems for the protection of desulphurization installations, Glasflake systems for internal protective coatings and insulation of metal and concrete tanks, facilities for desalinated water and wastewater, pits of tank parks for the storage of aggressive chemical products, acrylate materials for anti-corrosion security systems and many more. The perfumery and cosmetics industry is developed in Sofia. The first factory for cosmetic products in Bulgaria—Aroma JSC, was founded in Sofia in 1924. The company is a leading European manufacturer of cosmetics and perfumery. It delivers its products worldwide, thus realizing a major part of its turnover in foreign markets. The company has implemented the ISO 9001 quality management system. Plovdiv district (Cluster 2) includes the production of sulfuric acid (Holding KCM 2000) and detergents (Medix, Alvina, Lex, Razor, Vir, Waix - Mekson Ltd). In Plovdiv, the perfumery and cosmetics industry is also represented by Bulgarian Rose-Plovdiv JSC, established in 1948 by uniting nationalized Rose and Mint factories. The company is a leader in the production of essential oils and natural fragrance products. In Asenovgrad, calcium carbide is produced by Calcit JSC. The "Insa" Ltd. company, situated in the town of Rakovski, is one of the main producers of over 200 lubricating products (modern semi-synthetic and synthetic engine oils of a new generation, oils for all branches of industry, marine, transmission, vacuum and other types of lubricating oils, greases, and special automotive consumables) on the Bulgarian market. In the district of Plovdiv, during the studied period, the share of employees in the chemical industry was the highest in Bulgaria.

5.3. State and environmental regulations

At present, especially in the territory of the member states of the EU, the production of the chemical industry is strictly regulated. It must comply with and meet many environmental norms. An example of such regulation is the relatively recent addition to the EU Industrial Emissions Directive, from the end of 2022, which affects over 3,000 enterprises from the chemical industry on the territory of the EU member states. This is especially true for productions related to inorganic chemistry. On the other hand, in certain cases, the state gives preferences related to taxation, which stimulates the development of the industry in some of its areas.

5.4. Provision of skilled labor

The localization of enterprises provides them with qualified labour. This means that most of the enterprises in the industry are located near the big cities, where there are more opportunities for such a resource (Dimitrov, 2002). The enterprises of the chemical industry in Bulgaria are in the regions of Sofia (the capital) (Cluster 5), Plovdiv (Cluster 2), Varna (Cluster 3), Burgas (Cluster 6), Veliko Tarnovo (Cluster 1), Sofia (district) (Cluster 4), and Shumen (Cluster 1). These districts have the largest work labor: Sofia-capital (696,300), Plovdov (314,700), Varna (224,900), Burgas (183,500), Veliko Tarnovo (119,400), Sofia district (118,800), and Shumen (86,400) (NSI, 2022). Specialists in the field of chemical industry are also trained in these fields at the Faculty of Chemistry and Pharmacy (Sofia University "St. Kliment Ohridski"), University of Chemical Technology and Metallurgy in Sofia, University of Plovdiv "Paisii Hilendarski" in Plovdiv, Varna Free University "Chernorizets Hrabar", University of Veliko Tarnovo "St. Kiril and Metody", University of Shumen "Konstantin Preslavsky", and others.

6. Conclusion

To the best of the authors' knowledge, this study is the first to use ArcGIS pattern and cluster analysis tools to assess the territorial disposition of the chemical industry in Bulgaria, by applying indicators related to economic elements. The results show the chemical industry is characterized by high territorial concentration. The leading district in developing the chemical industry in the period 2010–2020 in Bulgaria is Varna, followed by Plovdiv, Ruse, and Sofia–capital. At the other pole are the districts of Vidin, Montana, Vratsa, Pleven, Lovech, Razgrad, Silistra, Targoviste, Sliven, Yambol, Pernik, Kyustendil, Blagoevgrad, and Kardzhali. At the NUTS 2 level in Bulgaria, the leading regions in the industry are the North-East, South-Central, South-West, and North-Central, and the opposite is the North-West region.

The applied methods based on modern spatial analysis in a GIS environment provide easier visualization statistical analysis, and data visualization access. The chosen grouping method, Grouping Analysis (K-means) is suitable for the study because it represents the real state of the chemical industry in Bulgaria. However, one drawback should be noted—the grouping of the areas is not in ascending order, but random.

The results of this research can inform the Ministry of Regional Development and Public Works of Bulgaria in preparing economic policies and taking measures for the individual clusters. Future research could focus on the application of the spatial statistics tool (Mapping Clusters) in ArcGIS (Esri), thus comparing the results of the present study with those of other tools included in the Mapping Clusters (Hot Spot Analysis, Optimized Outlier Analysis, Similarity Search).

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