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# Clustering and education: A study on European schools

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*The education standard is of utmost importance because it forms the basis of a country's future geoeconomic and socioeconomic progress and success. The study's main objective is to use cluster analysis to reveal the complex patterns, correlations, and relationships hidden between numerous education-related variables. The study uses clustering algorithms to group European nations with similar educational traits post-COVID-19. The selected variables – 44 European countries, Populations, GDP per capita, Scholars Enrollment Percentage, Number of Schools, and Successful Education Rate – combine to obtain a thorough framework for analysis. The study also explores the similarities and differences to predict the rate of successful schooling with statistical models. The clusters are vividly depicted in visualizations and tabular representations, which improves understanding of intricate data patterns. The categorization analysis opens doors to predictive modeling in the education sector, providing a potential tool for estimating academic achievements, notwithstanding some difficulties. These results highlight how analytics may improve the educational system.*

*Keywords: education, clusters, correlations, statistical analysis*

## 1. Introduction

The rich mix of nations, cultures, and policies that make up Europe's educational landscape forms a fascinating area for investigation and research. The amount of funds allocated to a nation's educational sector directly relates to the future the country is headed towards. If the country invests in its people, prosperity is guaranteed, and the literacy rate and GDP increase. However, according to studies (Gundlach–Wößmann 2001), there may not be a clear correlation between educational expenditure and school performance. This leads to another theory that the school system is strongly important in seeing growth, and, therefore, investing in knowledgeable educators or building them professionally from the ground up is a must for any county. Other studies (Cefai et al. 2015) state that creating a resilience curriculum for Europe's primary and elementary schools is also necessary. Cefai et al. (2015) explore the curriculum's goal, conceptual understanding, and the six main subject areas. Developing a proper curriculum helps European countries who have deployed this system to transcend above their neighbors. The educational ecosystem of Europe can be uncovered using data analytics to see the idiosyncrasies, patterns, and trends that lie within.

The importance of this study rests in its potential to alter European countries' educational policies and decision-making. Not only is education an aspect of society, but it also serves as a significant catalyst for social cohesion, economic development, and personal fulfillment. These revelations may enable governments to allocate resources more efficiently, teachers to adapt their curricula to cater to the needs of their students, and citizens to push for data-driven policy changes.

This study also promotes a spirit of cooperation and knowledge exchange in a globalized environment where nations can learn from one another's triumphs and difficulties. The data was collected from many trustful sources, such as the World Bank, Eurostat, United Nations, Google Scholar, Wise Voter, etc. Ultimately, the clusters generated by the study will reveal that most of the European countries have a moderate educational rate boasting a generous population. Through these findings, European nations could collectively stride towards a bright future sharing information and sending students to each other's neighbors to study and strengthen bonds.

## 2. Literature Review

A nation develops its human capital mostly through education. People who have completed their education are prepared to make meaningful contributions to the workforce and society at large (Janks 2014). The core of a country's workforce is made up of highly educated people, who promote innovation, productivity, and economic expansion. European countries, most of which are labeled as developed nations, know the importance of this fact. This can be further backed up by research that has been done into this topic to further understand what makes European nations stand out. One such study points out that in Austria the educational system is decentralized (Hörner 2007). This means that the decision power is not centralized but is distributed across various levels. It emphasizes the value of a legislative framework that enables school administrators to develop and carry out their objectives (Ristea 2014). The most successful models give school managers the most autonomy, according to a comparison of the legal framework of four decentralized educational systems: Romania, France, Spain, and Finland. It suggests that giving freedom while providing a basic curriculum to work with can do wonders for the school system.

Economic development is said to be primarily fueled by education, which affects growth and productivity in a number of ways. According to the human capital theory, education improves people's abilities and knowledge, which raises economic output and productivity. Higher incomes and better economic performance are two ways that investments in education pay off (Psacharopoulos–Patrinos 2004). This theory has been validated by later research, which demonstrates that nations with higher levels of education have faster rates of economic growth (Barro 2002). Productivity and education levels are positively correlated, according to empirical study of the topic. An increase in the average number of years of education have been linked to higher labor productivity and economic growth, according to studies (Qutb 2017). Education promotes technical proficiency, creativity, and resource efficiency, all of which support general economic growth. Although there is a favorable association, some studies highlight obstacles and restrictions (Pritchett 2001). Critics contend that economic policies and institutional quality, for example, may mitigate the effect of education on economic growth. Furthermore, the return on investment in education may differ depending on the type and quality of education (Hanushek 2003).

The Education Index, also referred to as the Successful Education Rate, assesses a nation's educational system using a variety of metrics to help with policy evaluation (Yang–Hu 2008). A higher score indicates a more educated workforce, which promotes economic growth, innovation, and less inequality. But this connection

has many facets and is affected by factors like infrastructure, stability, and legislation. A wider variety of educational accomplishments, including higher education levels like primary, secondary, and tertiary education, are taken into account by the education rate, in addition to basic literacy (Kono 2018). This all-encompassing indicator provides information about the degree to which people may access and complete different educational levels (Petrakis–Stamatakis 2002). It also represents the general level of education within a population. In order to guarantee that all societal segments have equitable access to high-quality education (Ololube et al. 2016), this statistic is essential for demonstrating the collective progress made in education and pinpointing areas that require policy reform (Mok 2001). The Education Index helps in mapping out the education disparities among countries (Van Hiel et al. 2018). There are notable differences in educational achievement, especially in low- and middle-income countries, demonstrated clearly in research that uses the Education Index to compare educational outcomes between nations (Hay 2020). Although it provides insightful information, there are several criticisms of the Education Index. Its exclusive focus on years of schooling, some academics contend, oversimplifies educational quality, ignoring elements like learning quality and educational results (Hauser 1997). Conversely, others draw attention to the fact that the index fails to take into consideration differences between nations or demographic groupings, which can conceal large gaps in education.

The Education Index has a big impact on educational changes and policies around the world since it offers a thorough assessment of educational accomplishments (Saarinen 2017). For example, countries like Ireland and Northern Ireland can assess their educational systems with the aid of the International Education Index (IEI) (Clark et al. 2023), which consists of 54 questions spanning nine variables. In order to help policymakers and improve the quality and accessibility of education, the Education Index is an essential tool for evaluating educational accomplishments worldwide.

All the cluster analysis literature for education is focused on the internal educational system, and how students and teachers' relation affects it (Rodgers 2002). This study focuses on the bigger picture. This study relates how the population, the number of public schools, and government spending are clustered in response to the education index, which brings in the effects of the national government overall (Gerged–Elheddad 2020). However, clustering has been used in profiling countries against set metrics. Contextual considerations do not readily account for the complexity of leadership for learning approaches. According to research on leadership at the school and national levels, there are no regional, linguistic, or political clusters at the country level. Instead, across schools in most nations, five leadership profiles stand out (Veletić–Olsen 2021). This implies that leadership profiles at the school level may be more pertinent to comprehending and enhancing leadership practice globally. Similarly, students that are likely to experience behavioral or academic issues can be found using behavioral clustering. Once kids have been identified, interventions can be put in place to help them (Huberty et al. 2010). For instance, students in the "at-risk" cluster may profit from additional academic support or social-emotional therapy. A more structured and supervised learning environment may be advantageous for the "disruptive" cluster of students. Behavioral clustering (Park

2016) can also be used to guide practice and policy in education. For instance, schools may use the findings of cluster analysis to create tailored interventions for students who are at risk for behavioral or academic issues. Cluster analysis is another tool that schools can utilize to pinpoint weak points in their curricula or instructional methods.

Cluster analysis has been deployed in the education sector to analyze how different nations are distributed, or how their finances are distributed. Indonesia is a case in point: due to its decentralized educational system, which gives the local government significant decision-making power, the government has the challenge of equally dispersing instructors around the country (Widiyaningtyas et al. 2017). On the other hand, Likas et al. (2003) analyzed to solve this problem in clustering algorithms like k-means, and he provided a useful method for determining the distribution of teachers and identifying areas with surpluses or shortages (Likas et al. 2003). However, this approach depends on the accuracy of the data collected so the policymakers would make sure of the local resources to ensure that the budget is assigned and spent wholly and equally (Krueger–Kumar 2004). Additionally, according to Krueger–Kumar (2004), the USA focuses more on vocational and other training, and thus this keeps the country ahead of others.

The present study emphasizes the necessity of comprehending the many patterns seen within European educational systems (Baye et al. 2005) and the possibility for data-driven insights to guide decision-making. Other studies presented information on a variety of topics, including school clustering and classification (Santamouris et al. 2007), government funding, and the distribution of public schools. Furthermore, the emphasis on techniques, such as clustering algorithms and classification models, has highlighted the significance of data-driven approaches in educational research.

## 3. Methodology

The study follows clustering data analysis techniques to find out how European nations cluster against the variables necessary to the educational index. This implies using clustering as well as descriptive statistics to gouge the data for insights and build upon the analysis.

The accuracy and reliability of the data utilized in this study were carefully monitored throughout the data collection process. Given their well-established track record in assembling extensive datasets relating to educational and economic indicators, a wide range of reliable sources, including well-known international organizations like the World Bank, UNESCO, and Eurostat, were consulted. The solid foundation of the analysis was built through the careful sourcing of the data, ensuring that the conclusions are supported by accurate and current data. The data comprised 44 European nations. This data was collected in 2023, which means that the results concurred from the analysis are applicable.

*Table 1.* Descriptive Statistics

| | Measurement | N | Min. | Max. | Mean | Std. Dev. |
|---|---|---|---|---|---|---|
| Population | Number of People | 44 | 518 | 144,444,359 | 16,824,160.11 | 28,462,385.926 |
| GDP Per Capita | USD | 44 | 3,531 | 233,617 | 45,282.48 | 46,472.465 |
| Government Education Financing | Percentage (%) | 44 | 1.9% | 8.1% | 4.459% | 1.3717% |
| Number of Public Schools | Count | 44 | 4 | 40,000 | 5,702.16 | 9,110.582 |
| Successful Education Rate | Percentage (%) | 44 | .56 | .94 | .8161 | .09749 |
| Valid N (listwise) | | 44 | | | | |

*Source:* own calculations

The descriptive statistics provide an overview of the important dataset characteristics, illuminating the differences and diversity among the 44 European nations studied. The population ranges from 518 to 144,444,359, with a mean of roughly 16.8 million and wide variation. Similarly, GDP per capita values range greatly, from $3,531 to $233,617, with a mean value of $45,282. With a mean of 4.459% and a range of 1.9% to 8.1%, government funding for education exhibits substantial variation. Public school enrollment spans from 4 to 40,000, with noteworthy variations, and the average enrollment is 5,702.16. Finally, the successful education rate shows moderate variation in educational outcomes, with values ranging from 0.56 to 0.94 and a mean of roughly 0.8161. It is clearly indicated that population is not balanced in European nations, with a wide variation. In addition, this adds up to varying figures for GDP per capita.

### *3.1. Data variables and education index indicators*

The study's educational attainment indicators comprise multiple critical variables that offer an all-encompassing perspective on the educational systems in 44 European nations. In order to compare educational measures in relation to the size of each country's populous, population acts as a contextual baseline. Economic success is reflected in GDP per capita, which affects the resources available for education and the standard of instruction provided. The amount of money the government spends on education is measured by the government education financing percentage, which shows how important and supported educational development is. In terms of accessibility and opportunity for students, the number of public schools indicates the presence of formal educational institutions. The successful education rate, which emphasizes the efficacy of educational programs and outcomes, evaluates the accomplishment levels within the educational system. When combined, these metrics offer a comprehensive picture of educational achievement and factors influencing it throughout the area.

### *3.2. Clustering and classification techniques*

K-means clustering was used to identify latent patterns in the data, grouping the classification of countries into different clusters based on their shared characteristics. This method served as a data-driven magnifying glass, enabling the automatic grouping of nations that had similar characteristics in terms of population, GDP per capita, government education financing percentages, the number of public schools, and successful education rates. The investigation revealed hidden linkages and groupings that might not have been visible through manual assessment alone through K-Means clustering. This methodological decision was crucial in helping to provide a thorough grasp of the various educational environments present in different European nations, ultimately opening the door for more insightful classification and analysis.

Through K-means clustering we can cluster and classify nations accordingly to their respective groups, which can tell us how many nations are relatively focusing on education.

### *3.3. Cluster analysis limitations and mitigation*

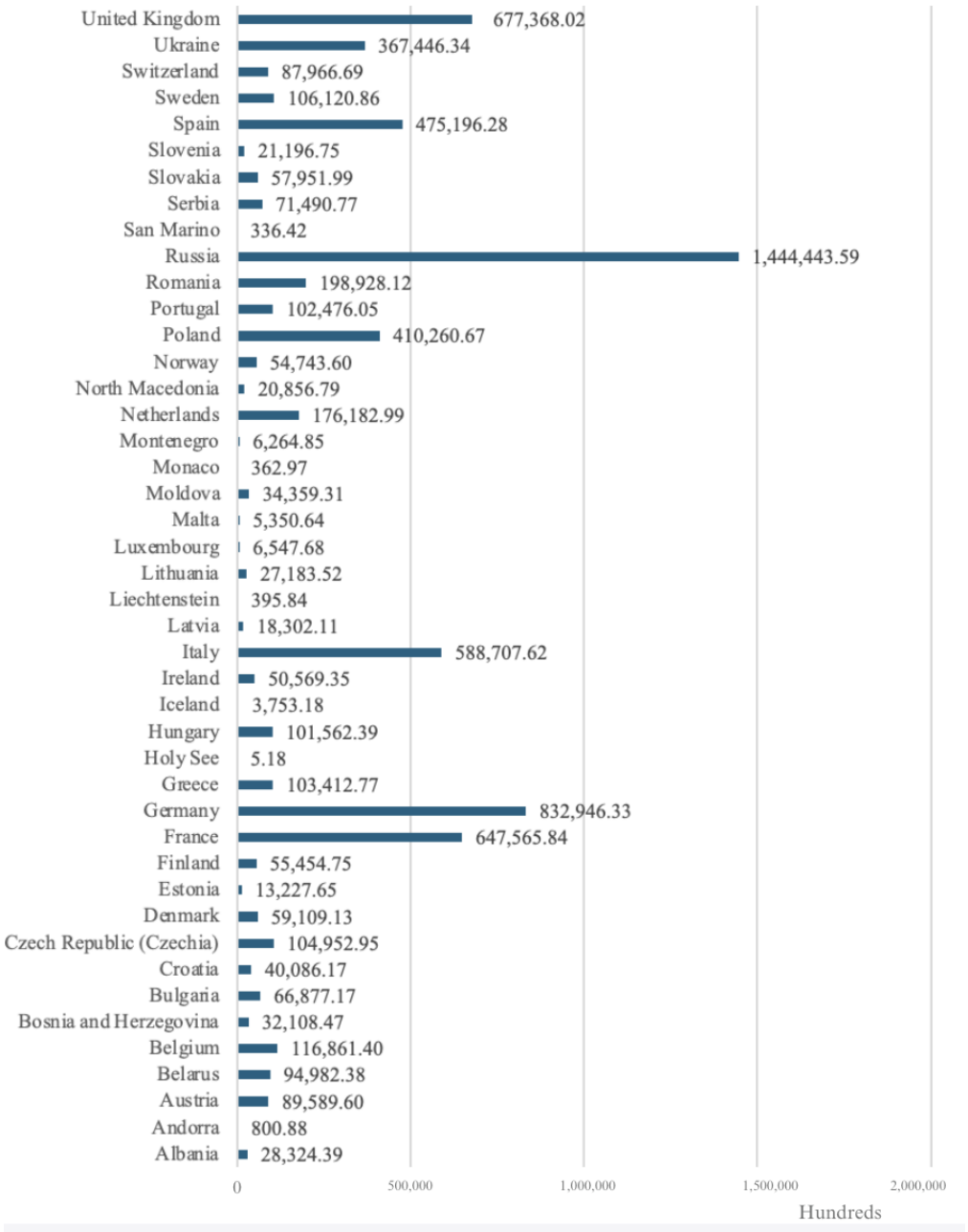
Although cluster analysis is an effective method for classifying related items, it has many common drawbacks and difficulties. Finding the ideal number of clusters is a major difficulty that can have a considerable influence on the validity of the findings. The elbow approach was used to solve this, enabling the visualization of the within-cluster sum of squares to pinpoint the point at which the benefits of adding more clusters reduce.

### *3.4. Distribution of the data variables*

A total of 44 countries were chosen for the study due to their representation of a broad and comprehensive cross-section of Europe, which is essential for the effective application of cluster analysis to comprehend educational attainment. Moreover, the inclusion of a wide range of countries from various regions–Western, Northern, Southern, and Eastern Europe–allows for a more nuanced exploration of the various factors influencing educational outcomes across the continent.

All the different data variables contribute towards a nations' education index or education rate. Therefore, it is important to map out how all the other variables venture out in relation to this. All the countries listed are in Europe, located throughout the continent: Albania, Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic (Czechia), Denmark, Estonia, Finland, France, Germany, Greece, Holy See (Vatican), Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, and the United Kingdom.

*Figure 1.* Simple bar mean of population by country/Europe




*Source:* own construction based on Eurostat (2023)

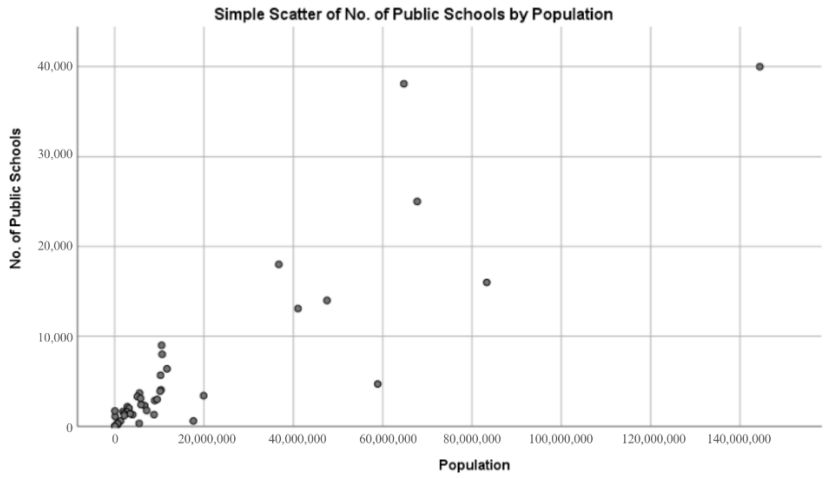
In Figure 1 the country with the largest population is Russia, with a population of about 143.4 million, while all the other countries are in the lower spectrum. This is a given, considering how Russia has been a superpower in the past, enjoying the economic advantages of such a sposition.

### 3.4.1. Relationship of public schools and the population

A range of variables interact dynamically to affect how many public schools there are in each location relative to its population. The first important factor is population size, with larger populations often requiring more public schools to meet citizens' educational demands. The inequalities between urban and rural areas also have an impact on this relationship, which is not only influenced by population size. Public schools are more concentrated in urban areas with higher population densities to meet local demand, but in rural areas there may be fewer but larger schools servicing a wider geographic area.

Figure 2 shows that as the population increases so does the number of public schools. But, it is notable in the figure that most countries have less than 10,000 public schools, entailing that they also have low population.

*Figure 2.* Scatterplot: Public schools by population

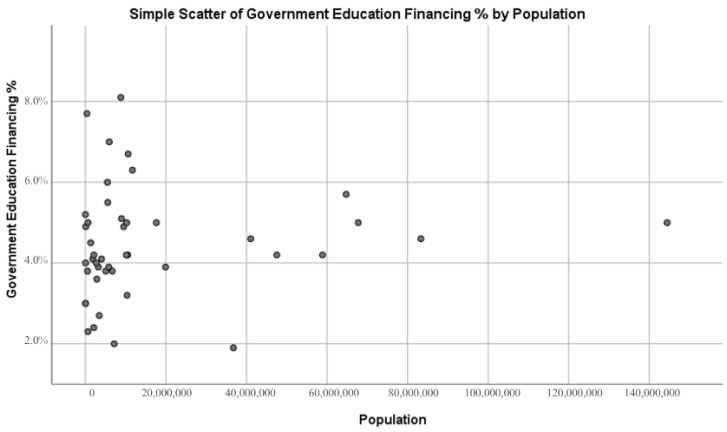



*Source*: own calculations

### 3.4.2. Government expenditure for education against population

People may guess that with increased population the government may increase their education budget. But, in the case of European nations, even small nations are mostly well off, as demonstrated in Figure 3. The figure indicates that even governments with low populations allocate a lot more budget than nations with more population.

*Figure 3.* Government education spending by population

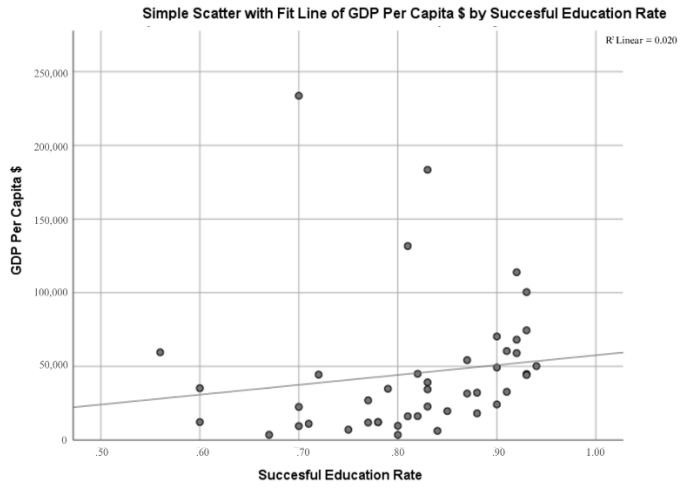



*Source*: own calculations

### 3.4.3. Relationship of successful education rate

A key tool for determining how well a nation's educational system is performing is the Education Index, which is frequently calculated as part of the Human Development Index (HDI). It includes a range of educational metrics, such as literacy rates, enrolment numbers for various educational levels, and overall educational attainment. A higher education index means that a large proportion of the population has access to high-quality education, which helps to create a competent and knowledgeable workforce. An educated workforce, in turn, often finds well-paying employment, stimulates innovation, and raises total production. Thus, nations with higher Education Index scores are more likely to achieve economic growth and prosperity.

*Figure 4.* Scatterplot: education rate vs. GDP




*Source*: own calculations

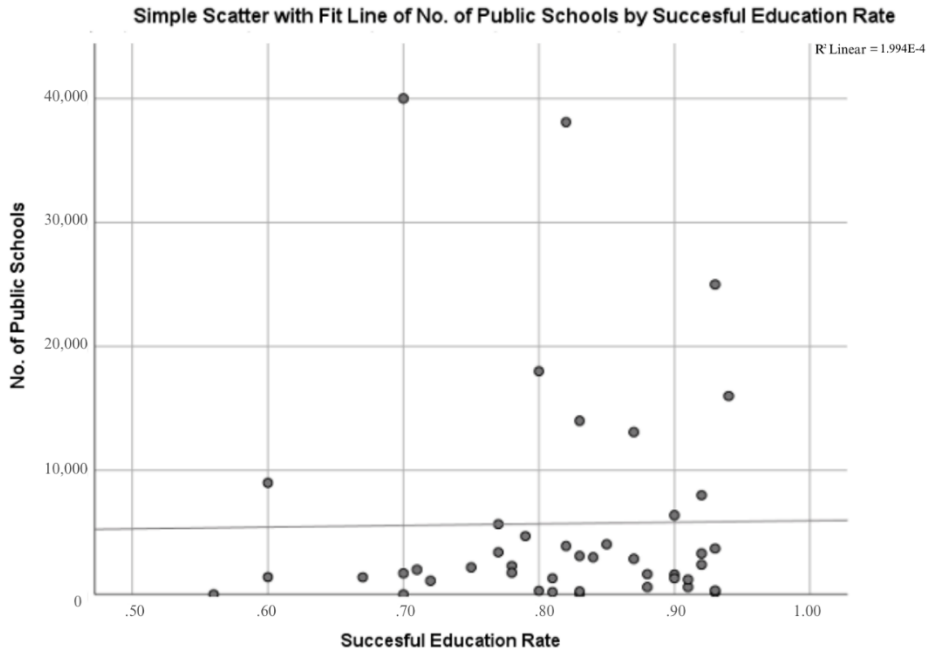
Figure 3 proves the point that with increased education rates the GDP per capita also increases, as indicated by the upward trend in European nations.

### 3.4.4. Public schools and education rate

Public schools are a pillar of accessible education and are often funded and run by the government to educate a large portion of the population. A nation's dedication to provide its inhabitants with educational opportunities can be gauged by the number of public schools in that nation. Increased enrollment rates, better access to education, and perhaps superior educational achievements are frequently associated with an increase in the number of public schools.

However, Figure 5 suggests that even countries with a high education rate have a low number of public schools and vice versa is also true. This means that countries need to strengthen their system either through decentralization or cluster-based learning.

*Figure 5.* Number of Schools




*Source*: own calculations

### *3.5. Correlation*

The educational index is a matric used to tell whether a country is on an educational success trajectory or not. Through correlation analysis the variables that impact the index can be analyzed.

*Table 2.* Correlations

| | | Population | GDP Per Capita, $ | Government Education Financing, % | No. of Public Schools | Successful Education Rate |
|---|---|---|---|---|---|---|
| Population | Pearson Correlation | 1 | -.166 | .087 | .885** | .044 |
| | Sig. (2-tailed) | | .281 | .575 | .000 | .776 |
| | N | 44 | 44 | 44 | 44 | 44 |
| GDP Per Capita $ | Pearson Correlation | -.166 | 1 | .202 | -.158 | .140 |
| | Sig. (2-tailed) | .281 | | .187 | .307 | .363 |
| | N | 44 | 44 | 44 | 44 | 44 |
| Government Education Financing % | Pearson Correlation | .087 | .202 | 1 | .101 | .523** |
| | Sig. (2-tailed) | .575 | .187 | | .513 | .000 |
| | N | 44 | 44 | 44 | 44 | 44 |
| No. of Public Schools | Pearson Correlation | .885** | -.158 | .101 | 1 | .014 |
| | Sig. (2-tailed) | .000 | .307 | .513 | | .928 |
| | N | 44 | 44 | 44 | 44 | 44 |
| Successful Education Rate | Pearson Correlation | .044 | .140 | .523** | .014 | 1 |
| | Sig. (2-tailed) | .776 | .363 | .000 | .928 | |
| | N | 44 | 44 | 44 | 44 | 44 |

**. Correlation is significant at the 0.01 level (2-tailed).

*Source:* own calculations

Table 2 indicates that there is a significant positive correlation between population and public-school enrollment (0.885**), indicating that as a nation's population rises, so does the number of public schools. Furthermore, a notable positive association between Government Education Financing (%) and Successful Education Rate emerges (0.523**, highly significant at the 0.01 level), suggesting that countries that allocate a larger share of their budgets to education typically have better educational outcomes. Though statistically insignificant ($p = 0.513$), the link between Government Education Financing (%) and the quantity of public schools is only marginally favorable (0.101). These relationships provide important insights by highlighting the complex interactions between population size, educational funding, and educational achievement rates.

From the above findings it is clear that the only variable affecting the successful education rate is Government Education Financing (%). This means that the greater the budget allocated to education by a government, the higher the educational index of the country, which thus increases the GDP as indicated in Figure 4.

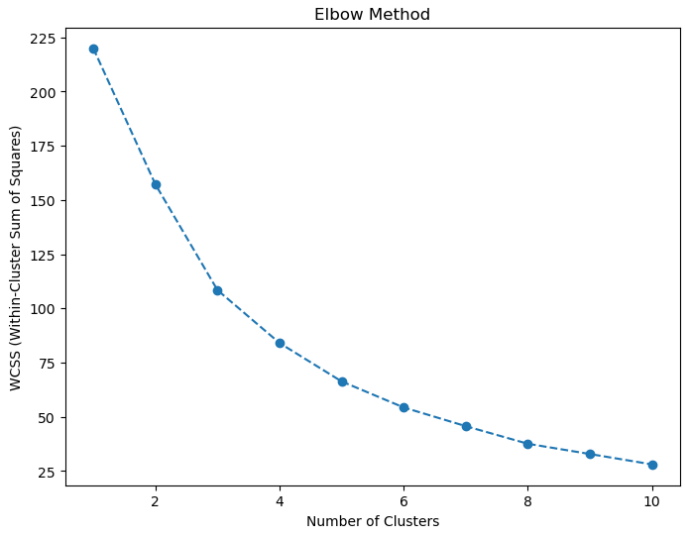
Cluster analysis is used in the methodology to find factors impacting education rates by analyzing educational data from European countries. Normalization and other pre-processing stages handle data variability and outliers, and the elbow approach is used to find the ideal number of clusters. By confirming cluster stability and relevance, the method guarantees reliable and understandable results.

## 4. Results and Findings

### *4.1. Finding the clusters: The Elbow Method*

Before analyzing any k-means cluster techniques, the optimum number of clusters must be found to represent the data. When employing clustering methods like K-means, the Within-Cluster Sum of Squares (WCSS) and the Elbow Method are crucial steps in figuring out the ideal number of clusters. In order to determine how compact a cluster is, WCSS calculates the sum of squared distances between each set of data points. In contrast, the Elbow Method is charting the WCSS for various cluster counts and locating the point on the graph where the rate of reduction abruptly changes, mimicking an "elbow." This point denotes the ideal cluster count since it is a compromise between reducing intra-cluster distance and avoiding excessive fragmentation. These techniques are useful tools for cluster analysis, aiding decision-making regarding the number of clusters to utilize by data analysts. Figure 6 demonstrates that the optimum number of clusters for the given data is three.

*Figure 6.* The Elbow Method




*Source:* own calculations

### *4.2. K-means cluster and findings*

With the help of the elbow method, we found out that three clusters can be made for our data. By using k-means the following three clusters were made. Table 3 represents the centers of each of the three clusters.

*Table 3.* K-means cluster

| Cluster | 1 | 2 | 3 |
|---|---|---|---|
| Population | 57,135,587 | 5,440,822 | 144,444,359 |
| GDP Per Capita $ | 35,479 | 48,182 | 9,510 |
| Government Education Financing % | 4.3% | 4.5% | 5.0% |
| No. of Public Schools | 18,412 | 2,278 | 40,000 |
| Successful Education Rate | .85 | .81 | .70 |

*Source:* own calculations

Cluster 1: Moderate GDP, High Population

*Population*: Cluster 1 has a median population of about 57.1 million people, which suggests that the nations in this cluster have generally average-sized populations. *GDP Per Capita*: The average GDP per capita in this cluster is relatively high, at roughly $35,479, indicating that countries in this cluster have a significant economic production per person. *Government Education Financing Percentage*: With an average government education financing percentage of 4.3%, these nations devote a respectable portion of their GDP to education. *Number of Public Schools*: There are typically 18,412 public schools in Cluster 1, which indicates a moderate degree of infrastructure. *Average Success Rate in Education*: The average success rate in education is 0.85, showing a comparatively high degree of academic success.

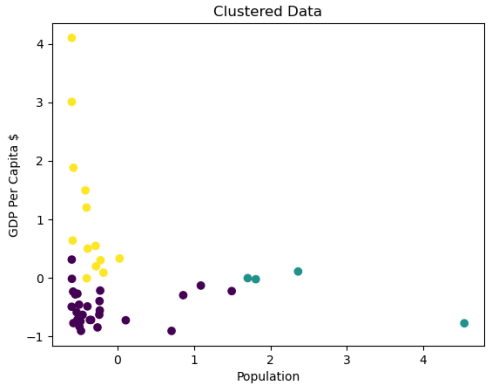
Cluster 2: High GDP, Small Population

*Population*: With an average of only 5.4 million people, Cluster 2 has a significantly smaller population than Cluster 1, showing that the countries in this cluster typically have a smaller total population. *GDP Per Capita*: This cluster's average GDP per capita is relatively high, at roughly $48,182, indicating significant economic affluence per person. *Government Education Financing Percentage*: The average government financing percentage for higher education is 4.5%, which is reasonable but significantly higher than Cluster 1. *The average number of public schools* in Cluster 2 is around 2,278, which suggests a less developed infrastructure for public education than in Cluster 1. *Successful Education Rate*: This cluster has a reasonably high degree of educational performance, with an average successful education rate of 0.81.

Cluster 3: Low GDP, Very High Population

*Population*: With an estimated 144.4 million people, Cluster 3 has the greatest average population size, indicating that the nations in this cluster have sizable populations. *GDP Per Capita*: At $9,510 on average, this cluster's GDP per capita shows lower economic prosperity for everyone. *Government Education Financing %*: These nations devote a larger proportion of their GDP to education than the other groups, with an average government education financing percentage of 5.0%. *Number of Public Schools*: Cluster 3 has an average of almost 40,000 public schools, which suggests a comparatively robust public-school infrastructure. *Successful Education Rate*: This cluster has a lower level of educational success than the other clusters, with an average successful education rate of 0.70.

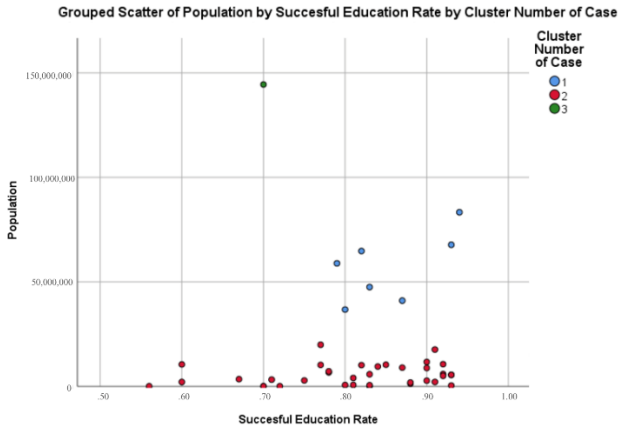
*Figure 7.* Plot of clusters in relation to GDP and population




*Source:* own calculations

In conclusion, Cluster 1 includes nations with average population sizes, high GDP per capita, average educational funding, average numbers of public schools, and average levels of academic accomplishment. Cluster 2 contains nations with smaller populations, high GDP per capita, slightly greater education financing, fewer public schools, and relatively high levels of educational accomplishment. Cluster 3 includes nations with sizable populations, lower GDP per capita, higher education financing, a sizable number of public schools, and lower levels of educational success. These clusters offer insights for additional investigation or policy concerns by classifying nations according to socioeconomic and educational traits.

*Figure 8.* Cluster distribution




*Source:* own calculations

Figure 7 shows the scatter plot distribution of cluster points. Apparently, most of the countries center around the second cluster. This is also obvious from the above figure. The second cluster has low population as well as a high education rate.

Each cluster's variability is exposed via the descriptive statistics for the clusters. In the first cluster, the standard deviations of the population (16,459,779.98), GDP per

capita (15,446.39), government financing of education (1.1838%), the number of public schools (10,588.04), and the successful education rate (0.06079) are all measured. In Cluster 2, there are 2,186.40 public schools, a successful education rate of 0.10172, GDP per capita of 50,477.72, government financing of education at 1.4348%, and population standard deviation of 5,020,486.92. Cluster 3 statistics are left out because all of the factors remain constant.

*Table 4.* Variability of the data variables with the clusters

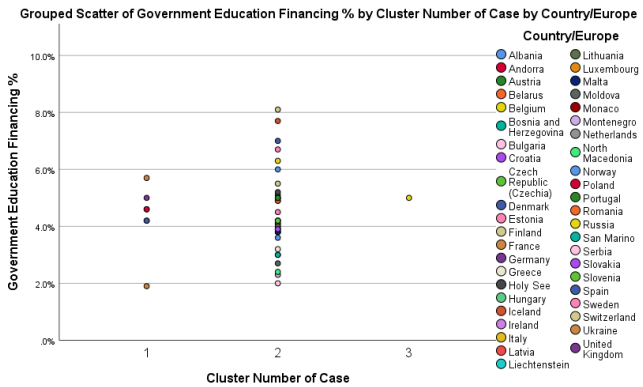
| Descriptives[a,b,c,d,e] | | | |
|---|---|---|---|
| Cluster Number of Case | | | Statistic |
| Population | 1 | Std. Deviation | 16,459,779.975 |
| | 2 | Std. Deviation | 5,020,486.920 |
| GDP Per Capita $ | 1 | Std. Deviation | 15,446.393 |
| | 2 | Std. Deviation | 50,477.720 |
| Government Education Financing % | 1 | Std. Deviation | 1.1838% |
| | 2 | Std. Deviation | 1.4348% |
| No. of Public Schools | 1 | Std. Deviation | 10,588.039 |
| | 2 | Std. Deviation | 2,186.399 |
| Successful Education Rate | 1 | Std. Deviation | 0.06079 |
| | 2 | Std. Deviation | 0.10172 |
| a. Population is constant when Cluster Number of Case = 3. It has been omitted. | | | |
| b. GDP Per Capita $ is constant when Cluster Number of Case = 3. It has been omitted. | | | |
| c. Government Education Financing % is constant when Cluster Number of Case = 3. It has been omitted. | | | |
| d. No. of Public Schools is constant when Cluster Number of Case = 3. It has been omitted. | | | |
| e. Successful Education Rate is constant when Cluster Number of Case = 3. It has been omitted. | | | |

*Source:* own calculations

### *4.3. Classification of countries according to clusters*

The countries are divided among the clusters as follows:

*Figure 9.* Countries distribution according to clusters




*Source:* own calculations

The countries in the various clusters are listed in Table 5. Cluster 1 consists of 7 countries, Cluster 2 consists of 36 countries, and Cluster 3 consists of 1 country only.

*Table 5.* Distribution of countries against their cluster number

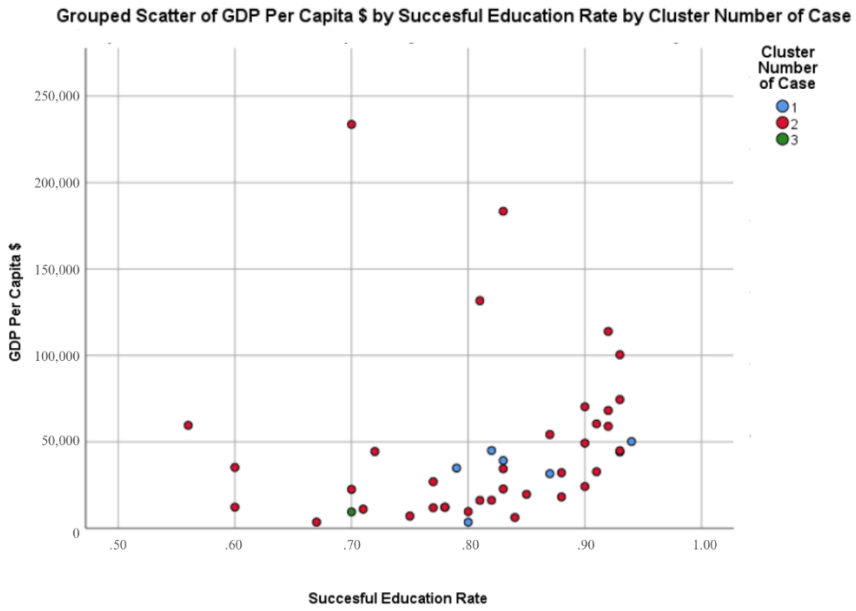
| Cluster Number of Case | 1 | 2 | 3 |
|---|---|---|---|
| Country/Europe | France | Albania | Russia |
| | Germany | Andorra | |
| | Italy | Austria | |
| | Poland | Belarus | |
| | Spain | Belgium | |
| | Ukraine | Bosnia and Herzegovina | |
| | United Kingdom | Bulgaria | |
| | | Croatia | |
| | | Czech Republic (Czechia) | |
| | | Denmark | |
| | | Estonia | |
| | | Finland | |
| | | Greece | |
| | | Holy See | |
| | | Hungary | |
| | | Iceland | |
| | | Ireland | |
| | | Latvia | |
| | | Liechtenstein | |
| | | Lithuania | |
| | | Luxembourg | |
| | | Malta | |
| | | Moldova | |
| | | Monaco | |
| | | Montenegro | |
| | | Netherlands | |
| | | North Macedonia | |
| | | Norway | |
| | | Portugal | |
| | | Romania | |
| | | San Marino | |
| | | Serbia | |
| | | Slovakia | |
| | | Slovenia | |
| | | Sweden | |
| | | Switzerland | |
| Total | 7 | 36 | 1 |

*Source:* own calculations

Table 5 clearly shows that most of the European nations have smaller populations, high GDP per capita, slightly greater education financing, fewer public schools, and relatively high levels of educational accomplishment. However, some

have large populations, the anomaly being Russia, as it has the largest population out of all the European nations.

*Figure 10.* GDP distribution by clusters




*Source:* own calculations

Figure 10 further validates the k-means cluster. The nations belonging in the 2nd cluster have education rates along with high GDP per capita.

## 5. Discussion

The clustering analysis of European countries offers an organized technique to comprehend the diversity of educational and economic environments on the continent. Using these clusters as a resource, European countries may cooperate to strengthen their educational systems, spur economic expansion, and promote a more prosperous and equitable future for all.

The clusters can provide important insights for the continuous growth of European nations. As an illustration, the clusters can be used by European policymakers to guide the creation of specialized economic and educational policies. Nations in Cluster 1 can offer insights on how to achieve both economic prosperity and high rates of educational success to other clusters by sharing best practices.

Governments can deploy resources more effectively if they are aware of the unique difficulties and advantages of each cluster. For instance, Cluster 2 nations may profit from higher public education spending or focused efforts to raise educational standards.

Collaboration between countries with comparable features can be facilitated by the clusters. This cooperation may also include commercial alliances, cooperative research projects, and educational exchanges.

### *5.1. Further research*

The results of this study suggest several intriguing directions for further investigation and analysis in the areas of education and economics in Europe. A more thorough examination of the exact elements influencing the performance of the nations in Cluster 1, which display high GDP per capita and good schooling rates, is one promising direction of research. To identify the laws, customs, and instructional methods that have produced such favorable results, researchers could carry out case studies or surveys. For other European countries attempting to attain comparable results, this might offer useful insights.

### *5.2. Limitations and data improvement*

Recognizing the limitations of the current study is essential for future research. One shortcoming is that the analysis was based on a small number of variables, and additional variables like cultural elements, teacher-to-student ratios, and infrastructure could have a considerable impact on educational and economic outcomes. To provide a full understanding of the topic, in a future study including a wider range of variables would be useful.

## 6. Conclusion

The delicate link between education and economic development in European nations has been clarified by this detailed study. Through the use of clustering and classification algorithms, various clusters have developed, each of which represents a particular fusion of educational and economic traits. These clusters shed important light on the various difficulties and triumphs that European countries have encountered in their quest for socioeconomic prosperity.

Cluster 1, which has a high GDP per capita and high success rate in education, provides an example of how to implement effective public policy and educational techniques. The nations in this group may help their peers succeed economically and academically by imparting invaluable knowledge. To close the disparities in economic development and educational quality, Cluster 2, which is dealing with these issues, needs targeted interventions and creative strategies.

The results also highlight the significance of including a wider range of factors in future study to provide a more thorough understanding of the complex relationship between education and economic development, including cultural factors, infrastructure, and political stability. The dynamics of these clusters through time can also be better understood via longitudinal research and evaluations of outside influences.

In conclusion, this study offers politicians, academics, and educators all around Europe a useful starting point. Nations can develop well-informed strategies, improve their educational systems, and promote sustainable economic growth by

utilizing the insights gained from these clusters. This research contributes to the ongoing effort to advance human development and prosperity in Europe. The pursuit of excellence in education and economic development is a lifelong journey.

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