

Software development for data analysis

Data analysis concerning infant mortality



Faculty of Cybernetics, statistics and economic informatics

A project by Aftodi ANA, ARNĂUTU VICTOR, BORLOVAN ANDREI & BUSUIOCEANU ȘTEFANIA

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# Introduction

This project aims to delve into the intricate web of socio-economic dynamics prevalent in European countries, utilizing a dataset sourced from EUROSTAT for the year 2020. This comprehensive dataset encompasses a diverse range of crucial indicators spanning health, demographics, education, poverty, lifestyle, infrastructure, and environmental sustainability. Through the application of robust analytical methods including Principal Component Analysis (PCA), Factor Analysis (Exploratory Factor Analysis), and Cluster Analysis, this project endeavors to unravel latent patterns, correlations, and pivotal insights embedded within the dataset. The exploration of these methodologies seeks to provide a comprehensive understanding of societal structures and environmental landscapes within Europe during the specified timeframe. The outcomes of this analysis could offer valuable insights for policymaking, societal interventions, and could pave the way for further research avenues in the socio-economic domain.

# Data source & time reference

Infant mortality, a crucial indicator of a society's well-being, encompasses the unfortunate loss of infants before their first birthday. It stands as a poignant reflection of a nation's healthcare system, socio-economic conditions, and overall public health landscape. In this analysis employing Principal Component Analysis (PCA), Exploratory Factor Analysis (EFA), and Cluster Analysis, the focus lies on comprehending the multifaceted aspects associated with infant mortality across European countries in the year 2020. By applying these analytical methodologies, the objective is to untangle the intricate web of factors impacting infant mortality rates, thereby elucidating potential correlations, hidden patterns, and critical insights that may guide targeted interventions and policy formulations aimed at reducing infant mortality rates across these nations. The data was retrieved from multiple databases from EUROSTAT, among which:

* <https://ec.europa.eu/eurostat/databrowser/view/hlth_cd_ainfo__custom_9196501/default/table?lang=en>
* <https://ec.europa.eu/eurostat/databrowser/view/tps00199/default/table?lang=en>
* <https://ec.europa.eu/eurostat/databrowser/view/demo_minfedu/default/table?lang=en>
* <https://ec.europa.eu/eurostat/databrowser/view/demo_fweight__custom_9197290/default/table?lang=en>
* <https://ec.europa.eu/eurostat/databrowser/view/tec00113/default/table?lang=en>
* <https://ec.europa.eu/eurostat/databrowser/view/hlth_ehis_sk3e/default/table?lang=en>
* <https://ec.europa.eu/eurostat/databrowser/view/hlth_ehis_al1e/default/table?lang=en>
* <https://ec.europa.eu/eurostat/databrowser/view/hlth_rs_bds1__custom_9198589/default/table?lang=en>
* <https://ec.europa.eu/eurostat/databrowser/view/sdg_13_10/default/table?lang=en>
* <https://ec.europa.eu/eurostat/databrowser/view/hlth_rs_physcat__custom_9332197/default/table?lang=en>

# Description of the variables

In the context of our infant mortality data analysis project, each selected variable holds specific significance, contributing unique insights into the multifaceted factors impacting infant health outcomes.

‘BabiesBornWithDiseases’ is a pivotal metric, encapsulating the genetic and congenital health profile of newborns, shedding light on inherent risks that may affect infant mortality rates. It includes conditions that might impact the health and survival of infants. Understanding the occurrence of diseases at birth is crucial for identifying potential genetic and environmental factors influencing infant health and mortality. Monitoring this variable can aid in the development of targeted healthcare strategies and interventions.

The variable 'Gynaecologist' refers to the presence and accessibility of gynecological care within a specific population. This variable plays a pivotal role in maternal and infant health outcomes. Access to gynecological care ensures that women receive essential reproductive health services, including prenatal care and guidance throughout pregnancy. The availability of gynecologists is integral in addressing and mitigating risk factors associated with adverse birth outcomes. Regular gynecological visits contribute to early detection and management of potential complications during pregnancy, reducing the likelihood of adverse events such as low birth weight and preterm births. The variable serves as a crucial indicator of the healthcare infrastructure's capacity to provide specialized care to expectant mothers, ultimately influencing neonatal health outcomes.

‘BirthsLower2kg’ represents the number of newborns with a birth weight less than 2 kilograms and is a critical factor associated with a higher risk of infant mortality. Monitoring this variable helps identify populations at increased risk and informs targeted interventions to improve maternal and fetal health. ‘BirthsBeforeTerm’ represents the number of infants born before completing a full-term pregnancy (before 37 weeks). Preterm births are associated with increased health risks for newborns. Both of these variables are critical indicators of neonatal health, emphasizing the vulnerability of premature infants and their increased susceptibility to mortality.

‘FertilityRate’ is a demographic variable that quantifies the percentage of women in a given population who give birth during a specific time period. In our context, the fertility rate is computed as the number of live births per 100 women of childbearing age in a given year. High or low fertility rates can impact the overall health and well-being of mothers and infants. This variable offers insights into maternal demographics, reflecting on the overall reproductive health of the population and its potential implications for infant well-being.

‘BirthsWithLowerEd’ emphasizes on a key socio-economic factor influencing health outcomes, mainly educational attainment. Mothers with lower educational levels may face challenges in accessing healthcare and adopting healthy parenting practices, impacting infant mortality rates. Socio-economic factors significantly influence access to healthcare and the overall well-being of mothers and infants. For this, the variable ‘AtRiskOfPoverty’ monitors births in economically vulnerable populations and helps identify disparities and guide interventions to improve outcomes. ‘Smoking’ and ‘AlcoholConsumption’ collectively delve into socio-economic and lifestyle factors. Maternal smoking and alcohol consumption during pregnancy are well-established risk factors for adverse outcomes that can lead to developmental issues in infants. These variables explore the nexus between educational attainment, economic stability, and health behaviors during pregnancy, providing a comprehensive view of the social determinants influencing infant mortality.

The ‘NoBeds’ variable illustrates the total number of beds available in Neonatal Intensive Care Units, a measure of healthcare infrastructure. The availability of NICU beds is critical for providing specialized care to premature or ill newborns. This variable reflects the healthcare infrastructure's capacity to handle critical cases, impacting overall survival rates for infants.

‘GreenhouseEmission’, the total amount of greenhouse gases emitted expressed in percentages, can indirectly affect health outcomes, including infant mortality. Greenhouse gas emissions may contribute to environmental stressors, and understanding their impact is essential for developing policies that promote a healthy environment for infants. Although unconventional in traditional infant mortality studies, this variable was included to examine the broader environmental context. It adds an ecological dimension to the analysis, recognizing the interconnectedness of environmental sustainability with infant well-being.

# Description of the observations

The observations in our dataset consist of data collected from 31 European countries, each representing a unique case study in the context of infant mortality. The selection of these countries provides a diverse cross-section of European regions, encompassing variations in cultural, economic, healthcare, and environmental contexts. The dataset captures a snapshot of each country's maternal and infant health landscape, allowing for a comparative analysis of the factors influencing infant mortality rates. The chosen countries offer a range of demographic profiles, healthcare systems, and socio-economic conditions, contributing to the richness and diversity of the dataset. By including countries with varying levels of development and healthcare infrastructure, we aim to uncover patterns and trends that transcend individual national boundaries, providing valuable insights that can inform regional and pan-European strategies for improving infant health outcomes. The observations, thus, serve as integral components in our analytical journey, enabling a nuanced exploration of the complex and multifaceted nature of infant mortality across the European continent.

# Data analysis approach

In the meticulous selection of these variables, our objective was to establish a comprehensive framework encompassing genetic, demographic, socio-economic, healthcare, and environmental factors. This diverse set of variables enables a nuanced understanding of the intricate interactions that collectively contribute to the complex landscape of infant mortality. Beyond individual variable analysis, the application of Principal Component Analysis (PCA), Exploratory Factor Analysis (EFA), and Cluster Analysis forms a triad of analytical methodologies. PCA aids in extracting principal components, revealing latent structures and interdependencies that might elude straightforward observation. EFA delves deeper into the underlying factors influencing the variables, providing a more granular understanding of their shared variance. Concurrently, Cluster Analysis identifies groups of variables exhibiting similar patterns, offering insights into potential subpopulations with distinct risk profiles. This multifaceted analytical approach is indispensable for uncovering hidden relationships and patterns among the chosen variables. Such insights are pivotal for the development of targeted interventions and policies, fostering a holistic strategy aimed at reducing infant mortality rates by addressing the diverse and interconnected facets of this complex phenomenon.

## Principal component analysis

Using the Kaiser criteria, we state that only 4 (C1, C2, C3, C4) principal components that have the eigenvalue bigger than 1 are statistically important. When visualizing the explained variance by the principal components, the steepness of the curve indicates the importance of each component in explaining the variance, C1 explaining most of it, degrading to C11.

From a statistical point of view, the factor loadings matrix in Principal Component Analysis (PCA) provides information about how each original variable contributes to each principal component. The factor loadings represent the coefficients in a linear combination of the original variables that forms each principal component. The factor loadings matrix in PCA is a fundamental component for understanding the relationships between the original variables and the principal components.

All these variables taking into account the location (European countries) show how infant mortality looks like (babies born with weight lower than 2 kilograms, parents that are at risk of poverty and do not afford prenatal care, the number of beds available for natal care (NICU beds), babies born with genetic malformations and diseases and the number of gynecologists).

C1 is computed by the birth characteristics such as birth weight, the socio-economic factors such as people at risk of poverty, the healthcare access (availability of neonatal intensive care units), congenital anomalies, and the number of physicians (gynecologists). C2 indicates big correlation with births from parents with a poorer educational background, environmental factors such as greenhouse emissions. C3 consists in the correlation between births specifics like births with lower duration of gestation and a lifestyle factor, daily smoking before and during pregnancy. C4 is about the contribution of fertility rate and births with malformations and genetic diseases.

The scores provide information about how each observation contributes to or is represented in the principal components. They are the first link between the observations (European countries) and the principal components.

We can conclude that C1, a composite factor incorporating birth characteristics, social and economic factors, healthcare access, is explained more in Germany, Turkey, France, Italy and Spain, statement that is suggested by the correlogram of quality of points. To understand what these five countries might have in common based on this explanation, it would be beneficial to analyze the potential shared characteristics or factors that contribute to the higher explanation of C1 in these nations.

* Similar Socioeconomic Patterns: income distribution, education levels, or employment structures;
* Comparable Healthcare Systems: accessibility, quality of healthcare services, and healthcare infrastructure;
* Common Cultural or Social Norms: clusters of different nationalities, ethnicities and cultures;
* Demographic Similarities: age distribution or population density;
* Policy Similarities: policy frameworks or government interventions in areas like social welfare, healthcare, or education.

Positive contributions from birth weight, socio-economic factors, and healthcare access variables might indicate a lower risk of infant mortality.

C2, on the other hand, has more correlation in Turkey, Iceland and Romania. C2 captures a complex combination of factors related to education (Romania - highest number of minor mothers in Europe that abandoned school, Turkey - higher level of uneducated females due to culture and religion), environmental impact, greenhouse emissions, especially in Turkey and Iceland that have higher rates on pollution. Higher positive values in C2 suggest a correlation with births from parents with a poorer educational background and exposure to environmental factors like greenhouse emissions. This component may highlight countries where infants are at higher risk due to these educational and environmental factors.

C3 is higher in Austria, Croatia, Turkey, Malta. Elevated C3 in these countries underscores the importance of public health interventions targeting smoking cessation during pregnancy. Initiatives may include educational programs, access to support services, and policy measures to reduce smoking among pregnant women. Smoking during pregnancy is associated with various adverse outcomes, including preterm birth, low birth weight, and developmental issues.

C4 is more present in Iceland, Austria, Croatia, France. Iceland having a small population and distinct genetic background can be a reflection of lower fertility rate and congenital malformations. In Austria, can be challenges addressing the healthcare practices, genetic screening, and lifestyle choices. Neonatal checks are not free and testing for genetical problems is expensive and not covered by the statutory health insurance. In France, prenatal genetical testing in not required, explaining the existent correlation.

Countries with higher values in these principal components may face challenges related to infant mortality based on specific factors identified in each component.

From the commonalities, we can conclude that the genetic factors, parents at risk of poverty and smoking explain more of the principal components, so they have a bigger impact.

## Exploratory factor analysis

For the Exploratory Factor Analysis, the sphericity Bartlett test indicates that at least one hidden common factor exists that explains the most variance of the model.

After the calculation of The Kaiser-Meyer-Olkin (KMO) indexes confirms that for every initial variable exists factorization potential. The global KMO has the value of: "KMO total: 0.6094295823829058", meaning that it has a mediocre potential of factorization. After the successive calculation of the statistical value of Bartlett, it was identified just one significant factor compared to the 11 observed variables.

Correlation between the extracted factors and the initial variables in a factor analysis is a measure of how well the factors explain the variance in the observed variables. In our case, we have a negative correlation, indicating an inverse relationship. A high negative correlation suggests that the extracted factors are capturing a substantial portion of the variance in the original variables.

For the analyzed factor, the number of gynecologists and beds have a strong negative relationship. These relationships indicate a relationship where lower availability is associated with higher values. Therefore, F1 seems to represent a factor associated with healthcare resources, socioeconomic conditions, and birth outcomes. Higher values of F1 are associated with fewer gynecologists, fewer beds, lower poverty risk, fewer babies born with diseases or low birth weights, and possibly higher greenhouse emissions.

The graphic for the quality of observations shows how well the observations are found, especially the European countries.

For the majority of the European countries, F1 is a determinant factor, as the graphic of the quality of observations shows. In case of the observation contribution on factor axis, most European countries are diffuse, but Germany is the particular observation that align well with the identifies factor.

## Cluster analysis

Using the Ward method and Euclidean metric, we first determine and analyze the optimal partition. Subsequently, we select a partition after examining the dendrogram graph. As observed, the optimal partition consists of two clusters.

Cluster analysis involves examining the distribution of each indicator within each cluster. This allows us to identify the peculiarities and differences between clusters. We will present several distributions that highlight clear differences between the two clusters of the optimal partition, detailed below:

|  |  |
| --- | --- |
| **Cluster** | **Country** |
| C0 | Belgium |
| C0 | Bulgaria |
| C0 | Czechia |
| C0 | Denmark |
| C1 | Germany |
| C0 | Estonia |
| C0 | Ireland |
| C0 | Greece |
| C1 | Spain |
| C1 | France |
| C0 | Croatia |
| C1 | Italy |
| C0 | Cyprus |
| C0 | Latvia |
| C0 | Lithuania |
| C0 | Luxembourg |
| C0 | Hungary |
| C0 | Malta |
| C0 | Netherlands |
| C0 | Austria |
| C0 | Poland |
| C0 | Portugal |
| C0 | Romania |
| C0 | Slovenia |
| C0 | Slovakia |
| C0 | Finland |
| C0 | Sweden |
| C0 | Iceland |
| C0 | Norway |
| C0 | Serbia |
| C1 | Türkiye |

For the information provided by Eurostat and the partition in 2 clusters, we can conclude that the countries in the cluster C0 exhibits lower values of Health Indicators (‘BabiesBornWithDiseases’, ‘BirthsWithLowerEd’, ‘BirthBeforeTerm’), lower values regarding Socio-Economic Factors (‘AtRiskOfPoverty’). We can conclude that, in Germany, Spain, France, Italy and Turkey, immigration reflects negatively on these countries that face a lot of immigration from poorer countries with lower standards of living and education.

For healthcare resources, countries in C1 have better healthcare infrastructure. The environmental impact is higher in C1, especially in Turkey, where the greenhouse emission is higher than would be sustainable under a global carbon budget.

For lifestyle factors, smoking and alcohol consumption are varied, but higher in the countries of C1.

Cluster C1, including major European economies, tends to have higher health indicators, socio-economic challenges, better healthcare resources, and greater environmental impact compared to Cluster C0, which consists of countries with generally lower values across these factors. The differences may stem from variations in economic development, healthcare systems, and lifestyle choices.

|  |  |
| --- | --- |
| **Cluster** | **Country** |
| C2 | Belgium |
| C2 | Bulgaria |
| C2 | Czechia |
| C2 | Denmark |
| C1 | Germany |
| C2 | Estonia |
| C2 | Ireland |
| C2 | Greece |
| C1 | Spain |
| C1 | France |
| C2 | Croatia |
| C1 | Italy |
| C2 | Cyprus |
| C2 | Latvia |
| C2 | Lithuania |
| C2 | Luxembourg |
| C2 | Hungary |
| C2 | Malta |
| C2 | Netherlands |
| C2 | Austria |
| C2 | Poland |
| C2 | Portugal |
| C2 | Romania |
| C2 | Slovenia |
| C2 | Slovakia |
| C2 | Finland |
| C2 | Sweden |
| C2 | Iceland |
| C2 | Norway |
| C2 | Serbia |
| C0 | Türkiye |

Analyzing the partition with 3 clusters, we can conclude that Cluster C1, including major European economies, tends to have higher health indicators, socio-economic challenges, better healthcare resources, and greater environmental impact compared to Cluster C2. Cluster C2 comprises countries with generally lower values across these factors. The observed differences may stem from variations in economic development, healthcare systems, and lifestyle choices. Additionally, Türkiye stands out in Cluster C0 with unique characteristics:

* Higher number of gynecologists compared to most other countries in Cluster C0, indicating a relatively well-developed healthcare infrastructure in this aspect;
* Higher number of births before term and lower birth weights compared to most other countries in Cluster C0, suggesting potential challenges in maternal and child healthcare;
* Lower levels of alcohol consumption due to religion;
* Higher risk of poverty due to immigration from middle east, culture or religion prohibiting females to work.

Turkey, as a Muslim and a non-UE country has a distinct position with cluster C0, suggesting a combination of healthcare, demographic, and socio-economic factors that differentiate it from the other countries.

|  |  |
| --- | --- |
| **Cluster** | **Country** |
| C3 | Belgium |
| C3 | Bulgaria |
| C3 | Czechia |
| C3 | Denmark |
| C2 | Germany |
| C3 | Estonia |
| C3 | Ireland |
| C3 | Greece |
| C2 | Spain |
| C2 | France |
| C3 | Croatia |
| C2 | Italy |
| C3 | Cyprus |
| C3 | Latvia |
| C3 | Lithuania |
| C3 | Luxembourg |
| C3 | Hungary |
| C3 | Malta |
| C3 | Netherlands |
| C0 | Austria |
| C3 | Poland |
| C3 | Portugal |
| C3 | Romania |
| C3 | Slovenia |
| C3 | Slovakia |
| C3 | Finland |
| C3 | Sweden |
| C3 | Iceland |
| C3 | Norway |
| C3 | Serbia |
| C1 | Türkiye |

The partition with 4 clusters reveals that Austria has its own cluster. Austria is concerned with lower fertility rates, smoking and more births before term than any other country analyzed.

|  |  |
| --- | --- |
| **Cluster** | **Country** |
| C3 | Belgium |
| C3 | Bulgaria |
| C3 | Czechia |
| C3 | Denmark |
| C4 | Germany |
| C3 | Estonia |
| C3 | Ireland |
| C3 | Greece |
| C4 | Spain |
| C4 | France |
| C3 | Croatia |
| C4 | Italy |
| C3 | Cyprus |
| C3 | Latvia |
| C3 | Lithuania |
| C3 | Luxembourg |
| C3 | Hungary |
| C3 | Malta |
| C3 | Netherlands |
| C0 | Austria |
| C3 | Poland |
| C3 | Portugal |
| C3 | Romania |
| C3 | Slovenia |
| C3 | Slovakia |
| C3 | Finland |
| C3 | Sweden |
| C1 | Iceland |
| C3 | Norway |
| C3 | Serbia |
| C2 | Türkiye |

For 5 clusters, Iceland will form a new cluster, characterized by very low gynecologist numbers, low hospital beds and higher number of babies born with diseases.

|  |  |
| --- | --- |
| **Cluster** | **Country** |
| C5 | Belgium |
| C5 | Bulgaria |
| C5 | Czechia |
| C5 | Denmark |
| C4 | Germany |
| C5 | Estonia |
| C5 | Ireland |
| C5 | Greece |
| C3 | Spain |
| C4 | France |
| C5 | Croatia |
| C3 | Italy |
| C5 | Cyprus |
| C5 | Latvia |
| C5 | Lithuania |
| C5 | Luxembourg |
| C5 | Hungary |
| C5 | Malta |
| C5 | Netherlands |
| C0 | Austria |
| C5 | Poland |
| C5 | Portugal |
| C5 | Romania |
| C5 | Slovenia |
| C5 | Slovakia |
| C5 | Finland |
| C5 | Sweden |
| C1 | Iceland |
| C5 | Norway |
| C5 | Serbia |
| C2 | Türkiye |

Therefore, for the 6 clusters analysis, Spain and Italy will form new clusters, having similar data on the majority of factors. We can conclude that demographics, culture, having the same roots can play a crucial role. France and Germany, being the most powerful and political involved countries in the European Union will form their own cluster, having similar politic inclinations and laws.

Cluster analysis can also group the variables. The variable clustering shows that:

* Cluster 0 emphasizes the relationship between healthcare, socio-economic conditions, and low birth weight;
* Cluster 1 focuses on the interplay between population-related factors and environmental considerations;
* Cluster 2 suggests a connection between educational factors and certain pregnancy outcomes;
* Cluster 3 highlights the relationship between lifestyle choices (smoking and alcohol consumption) and potential health and socio-economic implications.

# Conclusions

In this software development project for data analysis on infant mortality in European countries, a comprehensive exploration was undertaken to unravel the intricate web of socio-economic dynamics. The dataset, obtained from EUROSTAT for the year 2020, encompassed a wide array of indicators spanning health, demographics, education, poverty, lifestyle, infrastructure, and environmental sustainability. Robust analytical methods, including Principal Component Analysis (PCA), Exploratory Factor Analysis (EFA), and Cluster Analysis, were employed to decipher latent patterns and correlations within the dataset, aiming to provide valuable insights for policymaking and societal interventions.

The selected variables were carefully chosen to represent genetic, demographic, socio-economic, healthcare, and environmental factors. Each variable, such as 'BabiesBornWithDiseases,' 'Gynaecologist,' 'BirthsLower2kg,' 'BirthsBeforeTerm,' 'FertilityRate,' 'BirthsWithLowerEd,' 'AtRiskOfPoverty,' 'Smoking,' 'AlcoholConsumption,' 'NoBeds,' and 'GreenhouseEmission,' played a unique role in understanding the complex landscape of infant mortality. The observations, collected from 31 European countries, offered a diverse cross-section of cultural, economic, healthcare, and environmental contexts, contributing to a rich and comprehensive dataset.

The application of Principal Component Analysis (PCA), Exploratory Factor Analysis (EFA), and Cluster Analysis has unveiled hidden patterns, correlations, and distinct clusters within the dataset, contributing to a comprehensive understanding of infant mortality dynamics.

The Principal Component Analysis shed light on composite factors representing birth characteristics, socio-economic conditions, healthcare access, lifestyle choices, and environmental impact. Interpreting the results, countries like Germany, Turkey, France, Italy, and Spain exhibited higher values in the composite factor incorporating these variables, suggesting lower risks of infant mortality.

Cluster Analysis categorized countries into distinct groups based on similarities in health indicators, socio-economic challenges, healthcare resources, environmental impact, and lifestyle factors. The identified clusters facilitated the differentiation of countries with common characteristics, guiding the development of targeted interventions and policies tailored to specific challenges within each cluster. Cluster C1, including major European economies, demonstrated higher health indicators, socio-economic challenges, better healthcare resources, and greater environmental impact compared to Cluster C0.

Exploratory Factor Analysis delved into the underlying factors influencing the variables, offering a more granular understanding of shared variance. The identification of factors associated with healthcare resources, socio-economic conditions, and birth outcomes provided a comprehensive perspective on the determinants of infant mortality. The negative correlation between the number of gynecologists and beds suggested an inverse relationship with healthcare resources. The cluster analysis reinforced these findings, revealing distinct clusters based on healthcare infrastructure, socio-economic challenges, and environmental impact.

In conclusion, the project successfully applied advanced data analysis techniques to gain comprehensive insights into the multifaceted factors influencing infant mortality in European countries. The findings highlight the importance of healthcare access, socio-economic conditions, lifestyle, and environmental factors in shaping infant health outcomes. The identified clusters provide a nuanced understanding of country-specific challenges and opportunities, paving the way for targeted interventions and policy formulations to reduce infant mortality rates across Europe.