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Management of hospital resources and hospitalization in EU27: A factor analysis

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Abstract. The article aims to corroborate whether, in terms of public health and regional imbalances in the European Union for the year 2019, there is a correlation between the degree of wealth of a country and the way in which public health is managed and, likewise, to find independent factors that can group the various variables and explain them. Data from the 27 countries of the European Union were extracted from Eurostat, of which only 16 were subject to analysis, seeking to prevent conspicuous overestimation by missing data. Through the application of a data reduction methodology, Factor Analysis, seven variables were transformed into two factors: *Hospitalization* (Infant mortality, Hospital days of in-patients, and Live births) and *Hospital Resource Management* (Discharges, Hospital beds, GDP per capita, and Preventable and treatable mortality). Thus, it was found that the average number of days in hospital in countries with high GDP is equal to the average number of days in hospital in countries with low GDP (where GDP can represent the management of hospital resources and days in hospital are a proxy of the hospitalization). Proven by the factors, it was found, therefore, that the hospitalization is not significantly different, in the different levels of management of hospital resources in the countries, with Germany standing out as an outlier by boasting a greater number of births, more days in the hospital and a larger number of beds. It is also inferred that this scenario would be projected for the other eleven countries not considered in the Factor Analysis.

Keywords: Public health; Europe; Statistical data analysis.

1. Introduction

Public health and regional economic imbalances within Europe are undoubtedly important issues that are worthy to be analyzed. Many studies reveal that the health of the population tends to increase with the country's economic resources [1–3]. The thesis that economic resources are positively associated with health is often referred in the literature as the "health gradient". In one side, there is the idea that rich people can afford better living conditions and have better access to advanced medical care than poor people. In the other hand, poor health may lead to deterioration and depletion of economic resources, and in extreme cases, illness may even lead to impoverishment due to high cost of medical treatment [3]. Politicians and public health officials are deeply concerned about this "gradient", since inequalities between rich and poor people mean material differences in consumption as well as in life expectancy and quality of life [4].

The author [1] found that the relationship between income and health remained significant even after controlling for other factors, using an ordered probit instrumental variables framework. The authors [5] defended that income was positively correlated with health, but the effect was small and attenuated by other factors such as education and occupation. In [2], income was found to be a strong predictor of mortality, even after controlling for other factors.

The researchers [6] claimed that the causal link also runs in the opposite direction, from health to income: improvements in health can lead to income growth. Factors such productivity, education, investment in physical capital, demographic dividend may account for this relationship. Using a meta-regression analysis, [7] also found that health has a positive effect on economic growth. This effect is more evident in less developed countries.

Some researchers [8] argued that wealth is a superior measure of economic resources than income, due to the potential for income to vary significantly over time. At a micro level, the difference relies in considering income as a flow of money over a specified period of time, and wealth as a stock of value at a point in time [9]. Household wealth provides a more complete picture of household financial well-being and suggests deeper levels of material hardship than captured by income poverty measures alone [9].

The work of [10] and [11] argued for the superiority of wealth as a measure of economic capacity, due to its potential to accumulate over time and to be less affected by short-term shocks. In [12], a panel data regression model was used to show a U-shaped relation between wealth of a country (proxied by GDP per capita) and health (proxied by life expectancy). The author concludes that this effect of health improvements on wealth is negative in countries with an early stage of development. In this stage, usually there is a low human capital development, and an increase of the size of the population possibly has an adverse effect on wealth. In contrast, at a later stage of development, health improvements may induce an increase in human capital skills and have a positive effect on wealth.

At a micro-level, [13] found that the number of nights spent in a hospital was negatively correlated with changes in wealth for those individuals who did not have health insurance. [14] discovered that self-reported health status was correlated with changes in wealth, but changes in health conditions were not correlated with changes in wealth. To estimate the economic gradient in mortality, [15] applied self-reported health status and hospitalization measures in a regression analysis of mortality on wealth.

Given the importance of the above issues, this work aims to corroborate if there is a correlation between the degree of wealth of a country and the way public health is managed and, equally, to find independent factors that can group several variables and explain them, applying factor analysis. The paper's contribution is a macro level approach to the relationship between health and wealth, with country level recent data, using factor analysis as the main methodology.

This article is organized as follows: after contextualizing the study in the present section, the methodology applied is described in section 2. Section 3 discusses the results, and the final section concludes by highlighting the main findings of the current work.

2. Methodology

A quantitative methodology was adopted in this study where 7 variables were collected from the EuroStat database: Gross domestic product at market prices in euro per capita (*GDP per capita*), the number of *Live births and crude birth rates*, the number of deaths of children under the age of 1 year (*Infant mortality*), the number of bed days spent by patients in hospital with all causes of diseases (*Hospital days in-patients*), the number of available beds in hospital per 100,000 inhabitants (*Hospital beds*), the number of *Discharges from hospitals* (concerning pregnancy, childbirth and puerperium), per 100,000 inhabitants, and the *Standard preventable and treatable mortality rate* per 100,000 persons aged less than 75 years old. All variables are based on the year 2019 and are relative to the countries of the European Union (EU27).

The 27 countries will be studied to confirm whether public health policies are similar among them and whether imbalances (in terms of GDP) are the reflection of these policy measures. The factor analysis is going to be applied to study the relationships between variables in order to find a set of factors that express common aspects shared by the original variables.

3. Results

The results of the examination of the variables and the factor analysis were obtained using IBM SPSS version 28.

3.1. Sample Characterization

The sample was analyzed first, according to each variable individually, and afterwards, exploring possible relationships between variables.

GDP per capita

The average GDP per capita in the European Union countries is €27,678.89. The lowest is €6,630 and it comes from Bulgaria. The maximum value is €83,590 from Luxembourg. Through the analysis of these data it was possible to conclude that Luxembourg is the country with the highest degree of economic development in the European Union. The standard deviation is 17,470.447€, which means that the distance to the average of the values is high.

Live births and crude birth rates

The average number of births is 154,394.67. The country in which a small number of births (4350) are observed is Malta, and Germany is the country with the highest number of births, with a total of 778,090 live births. The standard deviation is 208,865, which means that the distance from the average of the values is high. The kurtosis coefficient is 4.086, thus it can be assumed that the distribution is leptokurtic.

Infant mortality

The average data on infant mortality for children under the age of 1 year is 522.19. Estonia has the lowest number of deaths, with a total of 22 deaths. On the other hand, France has a maximum value of 2864 deaths.

Number of days spent by patients in hospital

The European population spends an average of 33 018 985 days in hospital beds. Germany is the country that spends the most time in hospital, around 185 744 141 days.

Number of hospital beds

Sweden has a lower number of beds compared to the other countries. Germany has a much higher number, around 792 beds per 100 thousand inhabitants. The number of beds may be explained by the fact that Germany has patients spending a higher number of days in hospitals, so there is a need for more available beds.

Discharges from hospitals

The number of discharges from the hospitals in Cyprus is 533,7 per thousand inhabitants, which is the minimum value compared to the other countries. Ireland is the country with the highest number of discharges. Considering the number of hospital beds (288,04), it can be perceived that it is a low value, which can be explained by this high number of discharges.

Standard preventable and treatable mortality rate

Preventable mortality refers to mortality that can mainly be avoided through effective public health and primary prevention interventions. Treatable mortality can mainly be avoided through timely and effective health care interventions. The long-term objective for this indicator is considered to be a value of 150. In the sample, the average mortality rate is 283.48 deaths per 100,000 persons aged less than 75 years old. The minimum value is 164.86 and corresponds to Italy. The maximum value is 504.58 and concerns Romania.

Outlier detection

Before applying factor analysis, the assumptions must be verified. Regarding the normality of variables, the Shapiro-Wilk test allowed to conclude that only three of the seven variables had a normal distribution: GDP, Hospital Beds and Discharges from Hospitals.

Concerning the existence of outliers, it was found that the normalized variables Live Births and Infant Mortality present one moderate outlier each and only the variable Hospital Days presents a severe outlier (Figure 1). However, in these three variables it can be observed a slight positive asymmetry (to the right), i.e., the outliers do not seem to affect the location measures. Therefore, these variables can be included in the factor analysis.

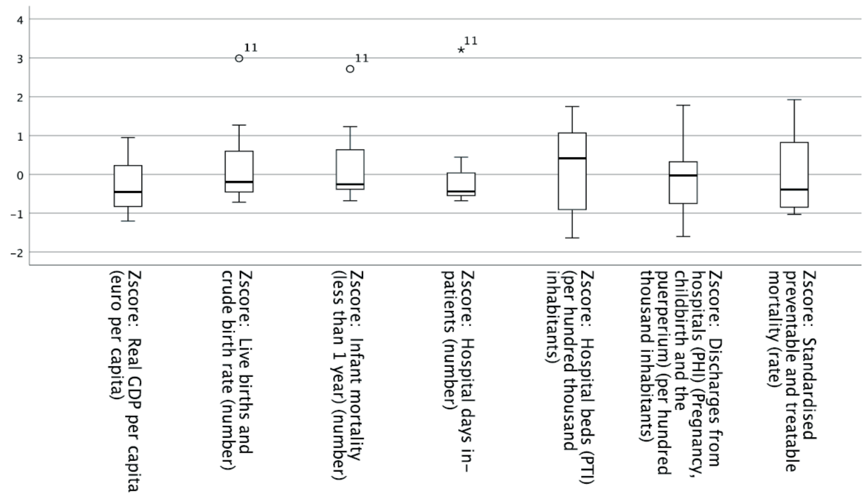

Figure 1. Boxplot of the standardized initial variables.

Relationship between health indicators and wealth of a country

Tests were performed to explore if there are significant differences between the average number of days spent in hospital in countries with low GDP and countries with high GDP. Therefore, countries were categorized into three classes according to their GDP: Low, Moderate and High. For all groups, the Shapiro Wilk tests produced p-values > 5%, ensuring normality of the variable Hospital days. Comparing the number of days spent in hospital of the groups of High GDP countries and Low GDP countries, the independent samples T-test resulted in $t = -1.140$ and $p = 0.314$, concluding that the mean number of days in hospital for high GDP countries equals the mean number of days in hospital for low GDP countries.

To group the variables into factors/latent variables, the Pearson correlation coefficients were checked, and scatterplots were inspected (Figure 2), seeking to ensure that correlations were high and, therefore, variables were more likely to share common factors.

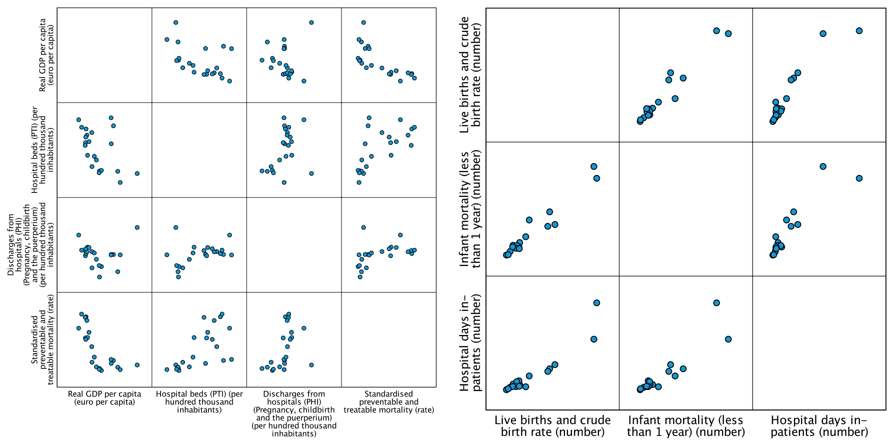

Figure 2. Scatterplots showing correlations between the initial variables.

Five of the Pearson linear correlation coefficients indicated a significant correlation at a 1% level of significance (marked with **) and two values indicated a significant correlation at a 5% level (marked with *), demonstrating a strong relationship between the variables involved, these being: GDP with Hospital Beds (- 0.442*) and with Preventable Mortality (-0.651**), Live Births with Infant Mortality (0.975**) and with Hospital Days (0.935**), Infant Mortality with Hospital Days (0.9**), Hospital Beds with Preventable Mortality (0.673**) and Discharges with Preventable Mortality (0.452*). Other significant correlations were Infant Mortality with Hospital Beds and Hospital Beds with Discharges which show a correlation greater than 0.3 (0.337 and 0.408, respectively) and a p-value < 0.10 ($p = 0.086$ and $p = 0.053$, respectively). The other two values higher than 0.3 (0.303 and 0.375) have a p-value higher than 0.1 ($p = 0.237$ and $p = 0.138$, respectively), so the null hypothesis is not rejected (R=0), so with 10% significance we can conclude that the correlation between variables GDP with Hospital Days and Hospital Days with Hospital Beds, respectively, are not significant. All other relationships were not mentioned for not being significant. A relevant number of significant correlations were found thus the factor analysis was applied.

3.2. Factor analysis

Considering the characteristics of the variables, the use of the Principal Components method is appropriate. As for the reference value of KMO, the closer to 1, the more appropriate the use of factor analysis. In this case, the relationship between the variables is considered by Kaiser to be an acceptable/reasonable relationship to apply the technique, since it is between 0.6 and 0.7 (0.658). The commonalities are all at least equal to or greater than 0.5 and 0.7 (the sample has less than 30 variables) [16]. Therefore, the variables have a good explanatory power/relationship by the principal component.

The first Kaiser's criterion recommends keeping only the components that present eigenvalues greater than 1, so that each component explains at least as much variance as each of the original variables. In this sense, two components (3.164 and 2.931) were considered, since the third component already has an eigenvalue lower than 1 (0.483), and these are ordered in descending order [17, 18].

In the second criterion, the Percentage of Total Variance Explained Criterion, it is recommended to retain sufficient principal components that can explain 70% to 85% of the total variance. According to this criterion, two components were also sufficient, as these would explain 87.073% of the variability of the 7 original variables (total variance).

The third criterion involves the analysis of the Scree Plot that represents the eigenvalues for each component, so the components that are farthest from zero must be selected, excluding, therefore, those that produce a practically horizontal line. Accordingly, using this criterion alone, the trend is more in the direction of three components [18].

However, as two of the criteria indicate the retention of two components and a third component would only explain the variance of about 6%, it seems more appropriate to retain only two components.

After deciding to retain two components, the loadings (weights) that vary between -1 and 1 are analyzed. However, performing a rotation of the system of axes (Figure 3), a more suitable interpretation of the components/factors is achieved, since the factorial weights are even higher or even lower (depending on the factor of belonging). That is, the loadings differ from each other and as a result, points are moved closer to the axes that represents the factor they are correlated with [17, 18]. Consequently, the rotation seeks to fade the intermediate values. For this purpose, the Varimax orthogonal (90º) rotation method was selected. Among the available methods in the SPSS system, this approach yielded the most favorable outcome after rotation by generating uncorrelated factors.

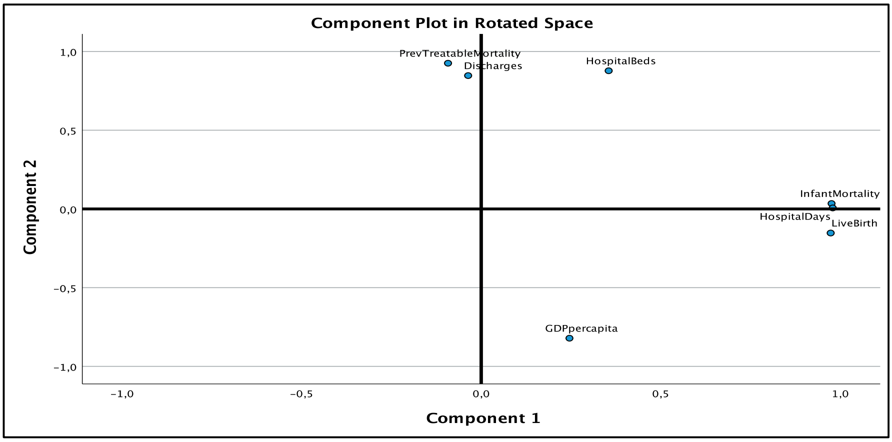

Figure 3. Component plot in rotated space using the Varimax method.

Accordingly, factor 1 consists of three positively correlated variables, with loadings above 0.5: InfantMortality, HospitalDays and LiveBirths (0.976; 0.979; 0.973, respectively). This factor was named *Hospitalization*, as both birth rates and infant mortality require a hospital stay, being its theoretical association with the variable days in hospital quite explicit and, hence, adequate. Factor 2 consists of four variables (positively correlated, except GDP), with loadings above 0.5 (absolute value): Discharges, Hospital Beds, GDP per capita and Preventable and Treatable Mortality (0.847; 0.877; -0.821; 0.925, respectively). This factor was denominated *Management of Hospital Resources*, due to the explicit management of hospital beds and discharges, as well as preventable and treatable mortality and the economic power of a country through the GDP per capita variable. Consequently, from seven initial variables two components were retained: Hospitalization and Management of Hospital Resources.

Finally, the values of each factor (non-observable hypothetical variable, that is used to represent variables) were estimated, in order to deduce the value that each element of the sample would obtain through the Thompson Method, the regression method, which seeks create scores that are correlated only with the own factor [18].

Aiming to use the two factors to test whether they are related, the values of the factors were compared with the results of the hypothesis test carried out before the factorial analysis, which included one variable for each factor.

The arrangement of each factor on the respective axes shown in Figure 4 was due to the fact that mortality can be affected/influenced in a certain way by the level of wealth of a country, so that *Hospitalization* (InfantMortality, HospitalDays and Live-

Births) was considered as a dependent factor (*y*) and the *Management of Hospital Resources* (Discharges, Hospital Beds, GDP per capita and Preventable and treatable mortality) as an independent factor (*x*).

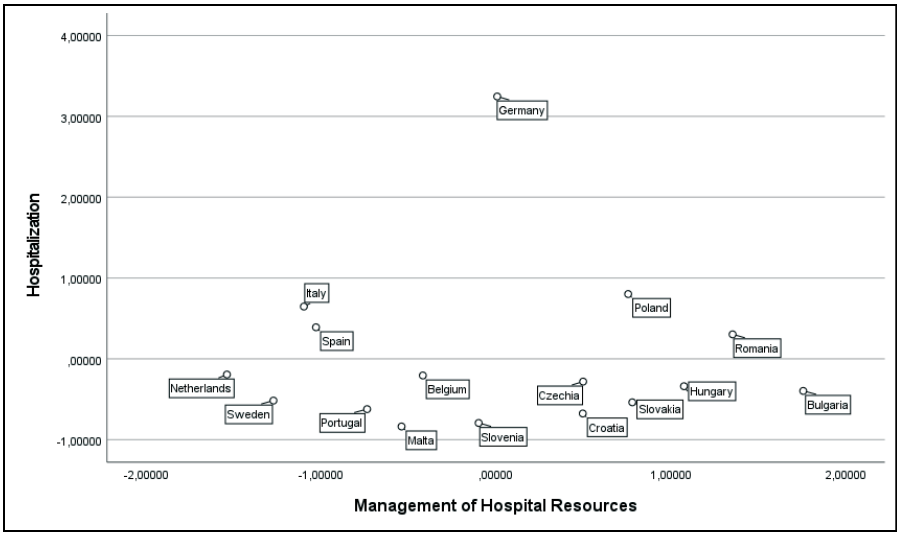

Figure 4. Scatter plot of the scores of the countries in the two factors.

In general, the hospital stay remains practically unchanged with the improvement in the management of hospital resources. Germany turns out to be the big outlier in this scenario. As seen previously, Germany was the country that had the highest number of births, the most days in the hospital and the highest number of beds. Surprisingly, this result doesn´t go against the result of the hypothesis test performed above. That is, in the same way that the average number of days in hospital in countries with high GDP is equal to the average number of days in hospital in countries with low GDP (where GDP can represent the management of hospital resources and days in hospital the hospitalization). Staying in countries with good management of hospital resources is not very different from staying in countries with 'worse' management of hospital resources.

4. Conclusions

This work has shown that factor analysis is undoubtedly a valuable tool when deducing, simplifying and drawing conclusions from large amounts of data. In this case, it was actually possible to create two variables representing seven already existing variables.

Unexpected result, when showing that different levels of management of hospital resources, namely the wealth of a country, tend to be not significant in terms of the variables studied.

It is therefore concluded that, although the study has not been carried out for all the countries of the European Union, it does provide a spectrum of what could happen in the countries not studied and it is expected that the situation will not change to a great extent. It is considered important to study this topic because it is a relevant social aspect such as public health and future interested parties are urged to use this model to assess, for example, whether there are regional imbalances within from the same country.

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