Data Visualization Analysis of COVID-19 in Norway, Poland and Moldova

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***Abstract*—This scientific article employs data visualization techniques to analyze the impact of the COVID-19 pandemic in three countries with varying Human Development Index (HDI) levels - Norway, Poland and Moldova. The study explores variables such as total cases per million, total deaths per million, new vaccinations smoothed per million and their correlation with socio-economic factors including HDI, GDP, stringency index and cardiovascular death rate.**

***Index Terms*—COVID-19, pandemic, HDI.**

I. Introduction

In the early stages of the SARS-CoV-2 pandemic, Europe experienced the most significant impact. European governments took various unprecedented measures to control the virus, albeit with differing timelines and levels of intensity. As the virus rapidly spread across borders, European nations confronted distinct socio-economic, healthcare and public health challenges. Assessing the pandemic's impact involves considering multiple indicators, with incident infection and mortality being the foremost reported outcomes. [1]

II. Materials & Methods

A. Data Sources

The data analyzed in this study were sourced from Our World in Data, a reputable and comprehensive platform that curates and provides open-access datasets on various global issues, including the COVID-19 pandemic. Our World in Data has been widely recognized for its commitment to transparency, data accuracy and accessibility. The utilization of data from this platform ensures a robust foundation for our analysis, as it aggregates information from authoritative sources such as national health agencies, international organizations and research institutions [2].

B. Data Processing and Analysis Tools

1) Unity for 3D Plot: Unity, a widely-used game development engine, was employed for creating 3D visualization in this study. Leveraging the capabilities of Unity allowed for the exploration of multidimensional data in an interactive and immersive manner. The 3D plot was instrumental in providing a unique perspective on the relationships between various variables, fostering a deeper understanding of the COVID-19 dynamics in the selected countries.

2) Matplotlib for 2D Plots and Barplots: Matplotlib, a powerful and versatile plotting library for Python, played a key role in generating 2D plots and barplots. The library's extensive functionality and ease of use facilitated the creation of clear and informative visualizations representing the temporal evolution of COVID-19 metrics and comparisons between different countries. Matplotlib's flexibility made it well-suited for illustrating trends, fluctuations, and patterns in the data.

C. Data Visualization Techniques

The study employed a combination of 2D and 3D plots to visually represent the dynamics of the COVID-19 pandemic and its correlation with socio-economic factors. Matplotlib's capabilities were harnessed for creating line charts, bar graphs, and other 2D visualizations, offering insights into the temporal aspects of the pandemic. Unity, on the other hand, provided a platform for building interactive 3D visualizations, allowing for a more immersive exploration of multidimensional data.

D. Python Libraries for Data Analysis

The analysis of the data was conducted using Python, a versatile programming language widely used for data science and analysis. Several Python libraries were instrumental in processing and analyzing the data:

- **Pandas:** Used for data manipulation and analysis, Pandas facilitated the handling of tabular data structures.
- **NumPy:** A fundamental library for numerical operations in Python, NumPy provided support for array manipulation and mathematical functions.
- **Matplotlib:** As mentioned earlier, Matplotlib was employed for creating various 2D plots and visualizations.

These tools and libraries collectively enabled a comprehensive analysis of the COVID-19 data, ensuring accuracy, transparency, and the generation of meaningful visual representations.

III. Variables Considered

A. Dependent Variables

1) Total Cases per Million: Represents the number of confirmed COVID-19 cases normalized by population size.

2) Total Deaths per Million: Indicates the number of COVID-19-related deaths adjusted per million people.

3) New Vaccinations Smoothed per Million: Represents the newly administered COVID-19 vaccinations per million people, providing a more clear and interpretable trend in the vaccination rollout over time.
Smoothing involves reducing noise, eliminating outliers and creating a more streamlined representation of the underlying trends or patterns within the data (in the context under examination, certain countries do not provide daily updates on vaccination data). The reported values have undergone a process known as smoothing, where each data point is replaced with an average value calculated over a chosen period (for this dataset it is 7-days) [2].

The normalization provided by metrics such as Total Cases per Million, Total Deaths per Million and New Vaccinations Smoothed per Million becomes especially crucial when comparing the pandemic's impact across different countries. In the case of our selected countries, this normalization allows for a more equitable assessment, considering variations in population size. It enables a nuanced understanding of how the virus has spread, the severity of its impact on mortality rates and the effectiveness of vaccination efforts in each country.

B. Independent Variables

1) Human Development Index (HDI): is a composite statistical measure that determines a geometric mean of normalized indices in three basic dimensions of human development: health, education and standard of living. The HDI provides a holistic perspective on a nation's overall development by synthesizing these key indicators into a single numerical value [3].

2) Gross Domestic Product per Capita (GDP per Capita): is a measure of the average economic output per person within a specific geographic area [4](in the context of this examination - a country).

3) Stringency Index: incorporates nine response indicators such as school closures, workplace shutdowns, and travel restrictions. These factors are then recalibrated to a scale ranging from 0 to 100, with 100 denoting the highest level of strictness. It's important to emphasize that this index only records the strictness of government policies. It neither assesses nor implies the appropriateness or effectiveness of a country's response. A higher score does not automatically indicate that a country's response is superior to those with lower scores on the index [5].

4) Cardiovascular Death Rate: is a death rate from cardiovascular disease in 2017 (annual number of deaths per 100,000 people) [2].

IV. Data Visualization

Data collected by *Our World in Data* contain information about many various factors, which may influence the main indicators describing the COVID-19 pandemic in a specific country. In the presenting project, the focus had been put on European countries, because of the comprehensive and thorough record of COVID-19 course in this region. The attention to detail in data collection and reporting allows to make an insightful analysis of the pandemic impact on chosen countries. An attempt was made to compare and contrast how countries with different levels of development reacted to the challenges of COVID-19 pandemic. Norway, Poland and Moldova were selected due to their distinct positions on the Human Development Index (HDI) amid European countries, which reflects a country's average achievements in fulfilling basic human needs such as health, access to education, standard of living and welfare. Norway comes as the best, being among the countries with the highest HDI in Europe, showcasing exceptional development in these key areas (it is worth noticing that Norway also has the highest HDI index in the world). Poland on the other hand stands close to the European mean, providing an insight for a moderately developed country. Lastly, Moldova - with the lowest HDI index in Europe - offers a perspective on the challenges faced by nations striving for improvement. In addition to HDI, a GDP per Capita index has also been compared to check on the nations' economic prosperity. Norway with the highest between these three represents a prosperous and rich economy. Poland with a medium GDP reflects a more typical economic scenario in Europe. Meanwhile Moldova, with the lowest GDP among the selected countries highlights economic challenges and disproportions in the region. Given relation had been presented in figure 1.

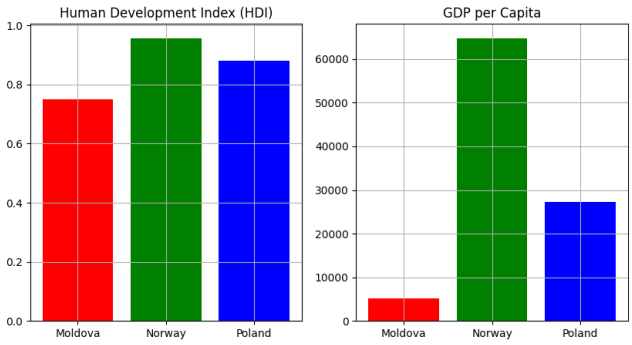

Fig. 1. *HDI* and *GDP per capita* between selected countries.

The Unity 3D plot (demonstrated in the figure 2) intuitively demonstrates the positive correlation between economic prosperity and human development. This visualization serves as a valuable tool for gaining insights into the socio-economic landscapes of the selected countries, informing policy decisions, resource allocation, and development strategies tailored to each country's unique challenges and needs. Norway (Index: 3) is positioned at a high point in HDI, indicating advanced human development, and is situated away from the origin on the GDP axis, signifying a robust economic standing. Poland (Index: 2) finds its place between Norway and Moldova, reflecting intermediate levels of HDI and GDP, emphasizing moderate development. Moldova (Index: 1) is positioned at a lower point in HDI, suggesting a lower level of human development, and is closer to the origin on the GDP axis, indicating a comparatively lower economic status.

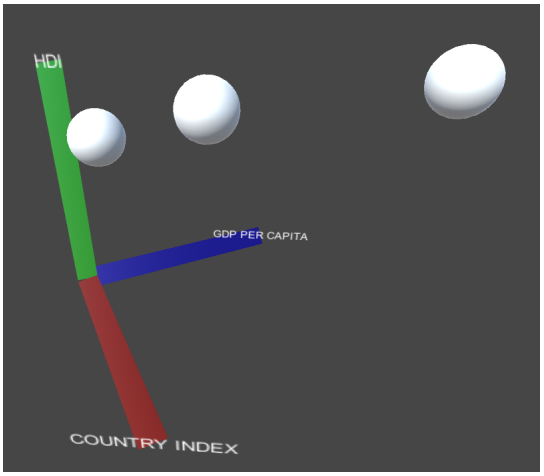

Fig. 2. 3D plot illustrating the relationship between Countries, GDP, and HDI for Moldova, Poland and Norway.

A. Analyzing COVID-19 Dynamics

Total Cases per Million metric has been changing in time. As it is shown in the figure 3, course of Total Cases per Million values increases relatively gently for Poland and Moldova and stabilizes at a similar level (with the notion the Moldova level of stabilization is grater) in comparison to the course of the values for Norway, where it can be observed that at the beginning the variable increases only slightly, followed by a sharp increase that quickly stabilizes at a much higher level compared to the other countries.

New Tests Smoothed per Thousand also changes over time (figure 3) and is characterized by irregular fluctuations due to the fact that there were periods of heightened virulence of the virus and thus countries conducted a larger number of tests during these periods. It may be noticed that Moldova began testing its citizens much later than Poland or Norway. However, those information are biased by the lack of data on testing frequency for this country for the specified time interval. New Tests Smoothed per Thousand curve for Norway reaches much higher values than for Poland or Moldova as its course mostly exceeds the other countries. It is also discernible that there was a period where all the nations performed a significantly higher number of tests than at other times.

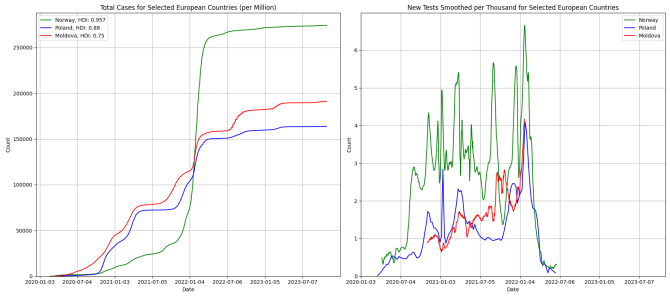

Fig. 3. Comparing COVID-19 Metrics Across European Countries with Varying HDI: Total Cases per Million and New Tests Smoothed per Thousand.

An important observation is that the time of occurrence of the highest fluctuations of the New Tests Smoothed per Thousand curves (in case of all countries) covers with the period of the most dynamic increase on the Total Cases per Million dependency.

Total Deaths per Million and Daily Vaccinated People for Selected European Countries (per Million) metrics provide insightful perspectives on the impact of COVID-19 and vaccination efforts. In figure 4, we observe the distinctive trajectories of these metrics for Norway, Poland, and Moldova. Comparing these two measures allows us to draw hypothetical conclusions about what might influence the course of the curves.

For Total Deaths per Million, Norway exhibits the smallest death rate, with the curve stabilizing at a consistently low level. In contrast, Moldova experiences the highest death rate, surpassing both Poland and Norway. The curve for Poland reflects a high level, slightly lower than Moldova's.

Shifting focus to Daily Vaccinated People, fluctuations characterize the curves for each country. Notably, dynamic growth periods overlap for all three nations, albeit with varying magnitudes of deviations. Norway demonstrates the greatest fluctuations, followed by Poland, while Moldova experiences the smallest deviations. The synchronization of dynamic growth periods suggests a coordinated effort in vaccination campaigns across these European countries.

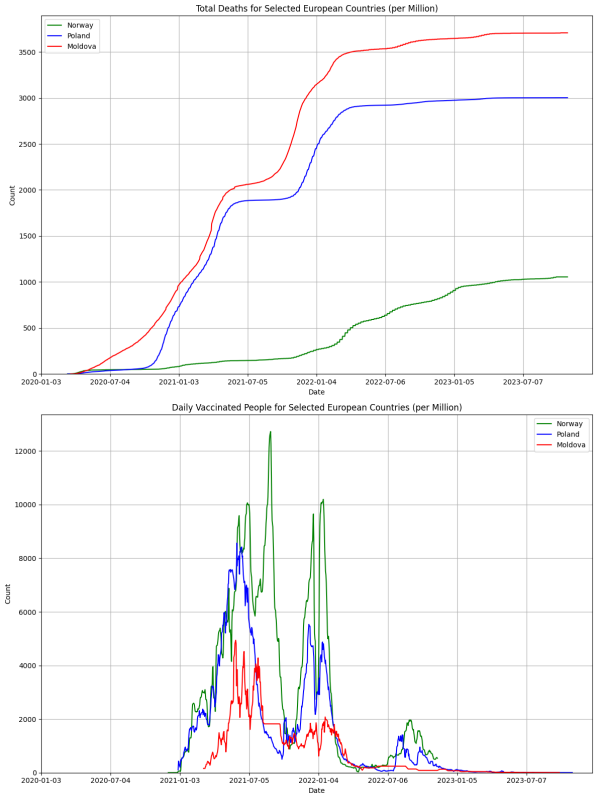

Fig. 4. Comparing COVID-19 Metrics Across European Countries with Varying HDI: Total Deaths per Million and Daily Vaccinated People for Selected European Countries (per Million).

Examining the Stringency Index across Norway, Poland, and Moldova (figure 5), we discern a pattern of similar values during specific time periods. Notably, there are instances of both high and low stringency, creating a dynamic temporal profile.

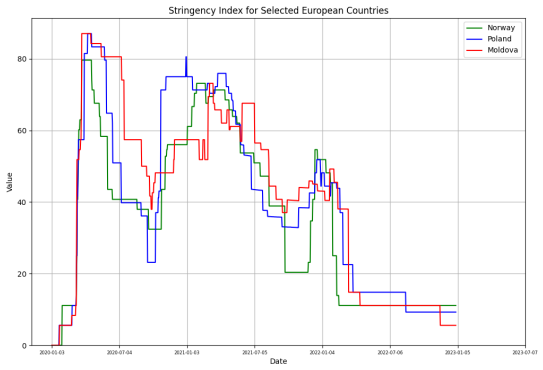

Fig. 5. Stringency Index Across European Countries with Varying HDI.

In the initial phases, the Stringency Index for all countries experiences a substantial increase, reaching levels of more than or around 80. This period likely corresponds to the early stages of the COVID-19 pandemic when stringent measures were universally implemented. It's noteworthy that the Stringency Index exhibits synchronicity across the selected countries during certain time intervals. The observed highs and lows align temporally, indicating coordinated adjustments in response to the evolving dynamics of the pandemic.

The ongoing COVID-19 pandemic has underscored the critical intersection between cardiovascular health and infectious diseases. Individuals with pre-existing cardiovascular conditions are at a higher risk of severe outcomes from COVID-19. Understanding the baseline CVD (cardiovascular death rates) in Moldova, Poland, and Norway is crucial for anticipating and addressing potential vulnerabilities within each country's population during the pandemic. Moldova, Norway, and Poland are countries with diverse socio-economic and healthcare profiles, the comparison of CVD is helpful to assess and explain the mortality and difficulty of curing those COVID-infected individuals in these specific countries. In figure 6, distinctive patterns emerge in the Cardiovascular Death Rate (CVD) across the selected countries. Notably, Moldova exhibits the highest CVD, while Poland demonstrates a medium level, and Norway maintains a relatively low CVD.

V. Results & Discussion

The visualizations presented in this study provide valuable insights into the dynamics of the COVID-19 pandemic in Norway, Poland, and Moldova, considering various socio-economic factors. Analyzing the patterns observed in the visualizations allows for a better understanding of the pandemic's impact on these countries.

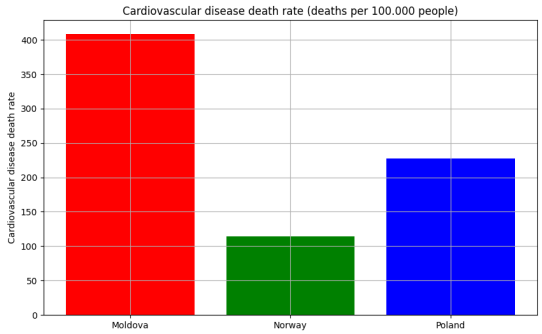

Fig. 6. Cardiovascular disease death rate (deaths per 100.000 people) between selected countries.

Despite Norway's high Human Development Index (HDI), it is intriguing to note that the total number of COVID-19 cases remained relatively high compared to Poland and Moldova. This unexpected finding prompts a closer examination of potential contributing factors. Factors such as testing strategies, healthcare infrastructure, public compliance with preventive measures, and the virus's behavior within populations could all play roles in shaping the observed patterns.

Another noteworthy observation is the similar Stringency Index values across Norway, Poland, and Moldova during specific time intervals. Despite comparable stringency measures, the total number of COVID-19 cases differs significantly among these countries. This discrepancy suggests that factors beyond strictness of government policies, such as public adherence to guidelines, cultural differences, and the effectiveness of public health communication, might contribute to variations in the pandemic's impact.

The influence of Cardiovascular Disease (CVD) on total deaths is a critical aspect to consider. Moldova, with the highest CVD rate, experiences a higher total death toll compared to Poland and Norway. The interplay between COVID-19 and pre-existing health conditions, especially cardiovascular issues, emphasizes the vulnerability of certain populations to severe outcomes. This finding underscores the importance of tailored public health interventions for individuals with underlying health conditions.

Furthermore, the relationship between total deaths and vaccinations is a complex interplay. While vaccinations are a crucial tool in mitigating the severity of the disease and reducing mortality, the impact can vary based on factors such as vaccine coverage, vaccine efficacy against emerging variants, and the speed of vaccination rollout. The observed patterns may indicate that the effectiveness of vaccination efforts is a significant determinant in the overall mortality rate.

In conclusion, the analysis of COVID-19 dynamics in Norway, Poland, and Moldova reveals nuanced relationships between socio-economic factors, government responses, and public health outcomes. The unexpected findings highlight the need for comprehensive research that considers a multitude of variables influencing the course of the pandemic. Policymakers

can use these insights to refine strategies, emphasizing the importance of tailored approaches that account for the unique circumstances of each country. Future studies could delve deeper into the specific factors contributing to the observed patterns, helping refine our understanding of pandemic dynamics and inform more effective public health responses.

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