Global Healthcare Expenditure Analysis

(INFO-I590 Data Visualization)

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Abstract:

Healthcare, recognized as a basic human right, often lacks equal accessibility for many marginalized populations. This project aims to utilize data visualization techniques to identify sources, trends, gaps, and opportunities in healthcare accessibility across various demographic groups globally. The intention of this study is to contribute to the creation of efficient, long-lasting, and equitable healthcare systems worldwide.

Introduction

Motivation:

This project is critically important and intriguing due to its focus on addressing healthcare inequality, a fundamental issue in global health. By employing data visualization techniques to illuminate disparities in healthcare access, particularly for marginalized populations, the project provides a data-driven basis for policy and decision-making. The project's innovative approach in handling complex healthcare data through visualization not only makes the findings accessible to a broader audience but also sets a new standard for effective communication and utilization of healthcare data.

Enhance the user's understanding of global healthcare financing sources, trends, disparities, and patterns, providing insights into top-performing countries, financing structures, and economic influences.
To derive valuable insights into how different countries, regions, and income groups allocate resources to healthcare, the relationship between economic development and sources of funding, and ultimately contribute to informed decision-making in the healthcare domain.

Healthcare expenditure can result in better provision of health opportunities, which can strengthen human capital and improve productivity, thereby contributing to economic performance. It is, therefore, important to assess the phenomenon of healthcare spending in a country [1].

Background:

Previous analyses have been narrowly focused on examining global health expenditure trends within particular world regions or individual years.

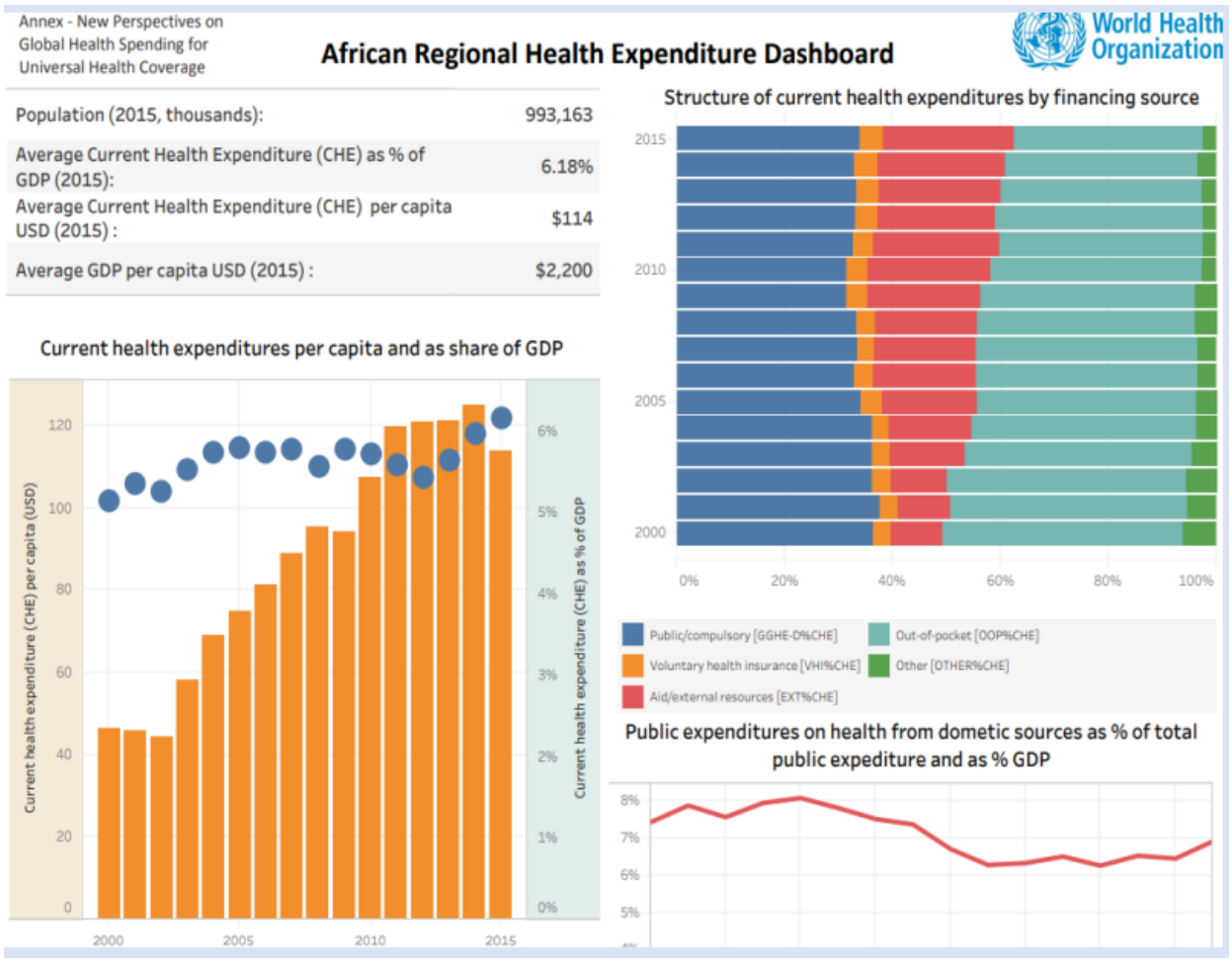

Fig1. WHO Visualization

This Fig1. is provided by the World Health Organization for the African region, offers valuable data but lacks the clarity, context, and interactivity necessary for stakeholders to draw actionable conclusions [2]. This fails the understanding of healthcare economics, particularly in the interpretation of trends, the identification of disparities, and the contextualization within global benchmarks.

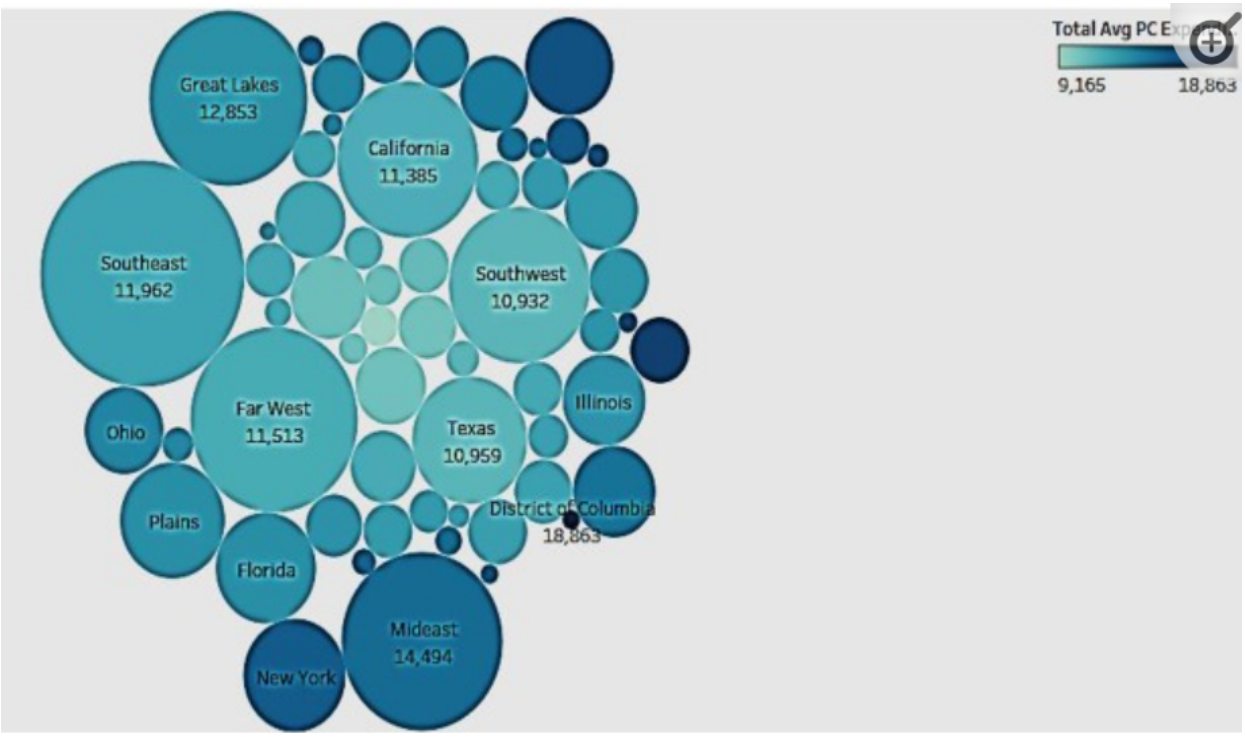

Fig 2. US Population vs Expenditure

Fig 2 shows an Overview of population size and total per capita healthcare expenditure, which is focused on only one region [1].

Our project aims to bridge these gaps by providing a more coherent, comprehensive, and comparative analysis of healthcare expenditures globally. This project visually analyzes 20 years of global healthcare spending data across countries and by income level. Interactive charts spotlight spending trends and inequities across regions over time. By enhancing data visualization and integrating contextual analysis, the project will enable a deeper understanding of the intricate relationships between healthcare spending and outcomes.

Contribution:

1. A simple line plot to see the global status of healthcare in the first sight of the app by giving an option to the user to select the year.
2. For population and expenditure, instead of a bubble plot, we have used a bar plot to compare in a more pleasing way with values hovering on each bar of the plot for the country USA; likewise, the same visualization can be done for any country or region.
3. For financing schemes, we have found a way of comparing the government and private sources out of the total healthcare expenditure by plotting a bubble chart.
4. To compare the different categories of the finance schemes, we have implemented a tree map for each country, which shows a clear picture instead of using a stacked bar plot as done previously
5. What changes have occurred over the decade within different regions are seen by drawing a sunburst chart which can be which have not been implemented before.

6. Moreover, time series and heat maps show the year-wise data for current healthcare expenditure as a % of GDP side by side to notice a significant change from the year 2019 to 2020 for the USA and Europe.
7. For geographical data, the dot distribution map is shown according to the different income levels for government spending schemes per capita(USD), which is the new contribution done in healthcare analysis.

Objectives:

1. Examine global healthcare expenditure distribution across financing schemes and government spending based on income levels per capita.
2. Investigate trends in health spending changes worldwide, emphasizing the percentage contribution of government and private sources in 2020.
3. Explore the relationship between population and healthcare expenditure per capita for the USA over observed years.
4. Analyze the evolving relationship between purchasing power parity, exchange rates, and out-of-pocket expenses globally since 2000.
5. Identify and compare the leading countries with the highest healthcare expenditure and assess variations in health spending across income groups within different regions over the years.

Process

Data Source:

Source: AWS marketplace [6].

About: The health expenditure CSV data tracks how much countries spend on healthcare as a percentage of their GDP. It also includes information on Purchasing Power Parity and government healthcare schemes, offering insights into global spending patterns and the impact of government initiatives on health budgets.

Structure: 4224 rows, 415 columns after doing data pre-processing.

Exploratory Data Analysis:

- Loaded raw global health expenditure dataset
- Identified and removed 2806 columns where missing >30% data
- Handled 2071 null values
- Filtered raw data dictionary to match cleaned columns
- Conducted initial EDA to understand features
- Addressed outliers & missing data issues

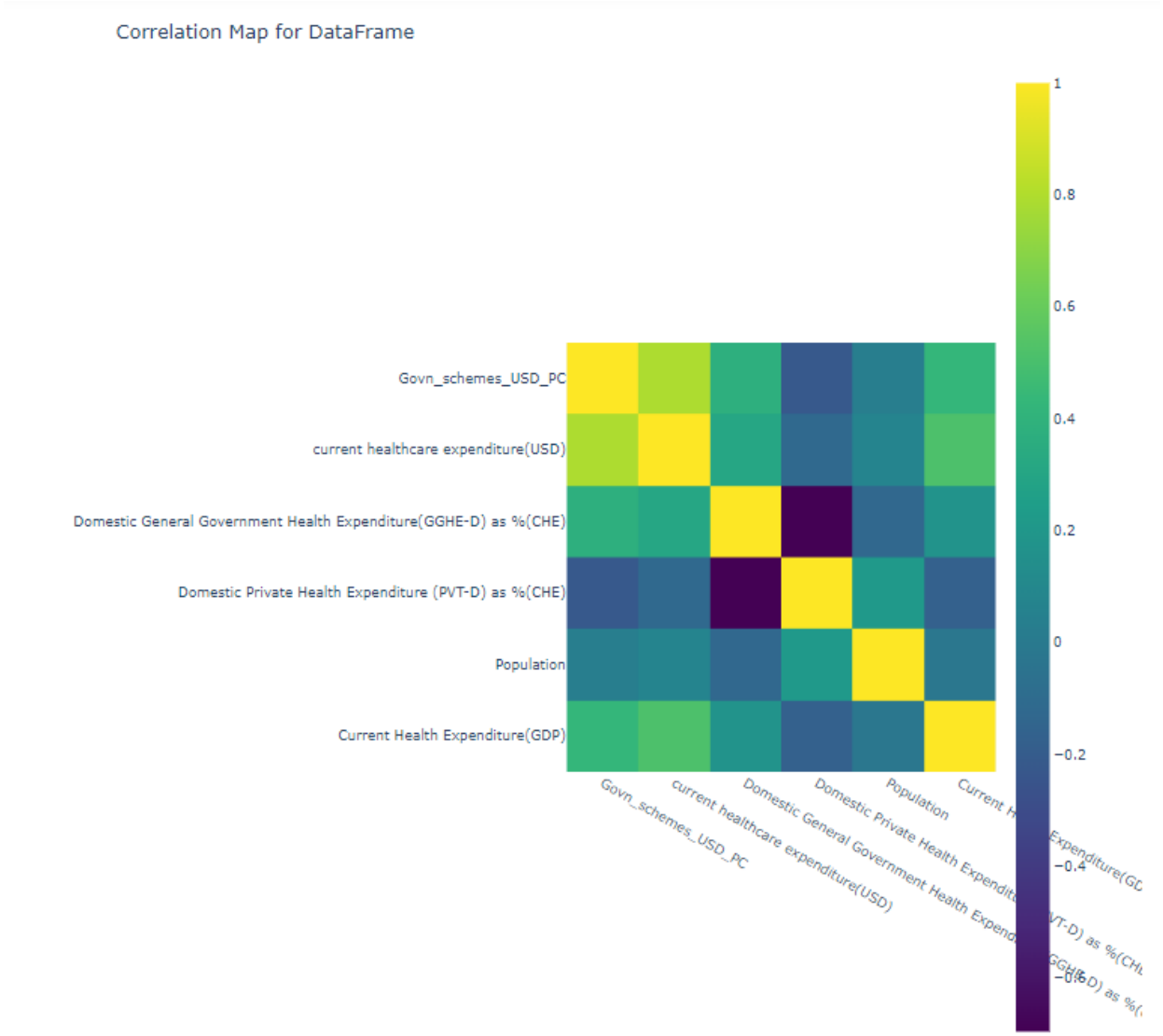

Fig.3 Correlation Matrix

Visualization Methods:

Distribution Analysis

1. **Treemap:** Hierarchy and proportion of healthcare financing sources.
   A treemap is a type of data visualization that displays hierarchical data as a set of nested rectangles. Each branch of the hierarchy is represented as a rectangle, which is then tiled with smaller rectangles representing sub-branches. Each large rectangle represents a country, such as the United States, United Kingdom, Brazil, etc. Within each country's rectangle, there are smaller rectangles that correspond to specific categories of healthcare financing.
   If the data is not normalized for factors such as population size, GDP, or purchasing power parity,, the treemap may not accurately represent the burden or efficiency of healthcare spending.

2. **Dot distribution map:** Government spending on schemes based on Income level.
   A dot distribution map is a specific type of visualization used primarily in geography and related fields to represent the distribution or density of a particular variable or phenomenon across a geographical area.
   The map uses colored dots to represent different countries, categorized by income levels such as low, lower-middle, upper-middle, and high income. The size of the dot correlates with the amount spent per capita; larger dots indicate higher spending. One of the possible ambiguities is that If the scale for the size of the dots is not clearly defined, viewers may have difficulty understanding exactly how much more one country spends compared to another.

Trend Analysis

3. **Line chart**: Regional Insight with Time Series and Moving Average.
   Time-series line charts are perfect for depicting trends over time, providing a clear overview of regional health spending patterns. The x-axis represents years, while the y-axis shows health expenditure as a percentage of GDP. Using colors to categorize regions enhances clarity. Grouping data by region and applying rolling averages ensures a smooth portrayal of trends, aiding in identifying long-term patterns. However, if there are a large number of regions, the line chart might become visually cluttered, potentially making it challenging for viewers to distinguish and interpret individual regional trends accurately.

4. **Bubble chart:** Public vs private spending on healthcare.
   It shows the percentage of the government and private sector spending out of the total current healthcare expenditures to view the relationship between the two sources. This plot is perfect for 3 variables because there are three numerical columns and hence, the x-axis and y-axis show the government and private spending, respectively, and the third dimension is shown as the size of the bubble. Also, the correlation between two variables is shown by the color for the user to identify the difference between the spending easily. Hence, this plot is perfect for size differentiation of one variable w.r t the other two variables which will be useful for highlighting the significant values. But this plot has one disadvantage that some bubbles are overlapping. Also, some bubbles might hide under the big bubbles and hence, the user will mislead with some of the information for which the bubbles are overlapping and are of the same color.

Relationship Analysis

5. **Bar chart:** US health spending vs population over time.
   This plot shows the population per capita and the current healthcare expenditure on the x-axis to represent their total value over the decade on the y-axis. This plot is suitable because the two variables can be compared side by side for any two years. Also, it gives the overall trend of the two variables, and trend comparison can be done to see the dependency of expenditure on the population as expenditure should increase with increasing population for a sustainable development. One downfall of this method is that the y-axis represents the value for both the variables. Hence, it becomes difficult to adjust

the scales for the both as there is a huge difference between the two. If the interval of the y-axis is increased, then the bar for expenditure will not be seen. Hence, it's important to choose the y-axis scale wisely.

Comparison Analysis

6. **Line chart**: Top 10 highest spending countries.
   This plot represents the top 10 countries in descending order to compare the current healthcare expenditure for different countries in the selected year. This visual is simple and easy to understand. The only con of this graph is that it's difficult to compare the top 10 countries for all the years, but users have the choice to select one by one and then compare it.

7. **Sunburst chart**: Compare Health Expenditure by Region, Income Group, and Country.
   Opting for a sunburst chart for analyzing health expenditure trends offers a comprehensive view of spending patterns. This includes insights into health expenditures (%GDP) across regions, the distribution of income groups within each region, and the variations in spending among countries within each income group over time. Creating distinct sunbursts for 2010 and 2020 facilitates the identification of changes in ring sizes and enables a straightforward comparison of ratios among regions. Nevertheless, if the number of elements in the chart increases, there's a risk of visual clutter. The intricate details may become harder to distinguish, potentially compromising the clarity and ease of understanding, especially when dealing with a large dataset.

8. **Radar/Spider chart:** Relationship between purchasing power parity and exchange rates expenses since 2000.
   The Spider Chart is a great choice for visualizing the relationship between purchasing power parity and exchange rates since 2000. It clearly shows the positive correlation between these factors using radial coordinates, making it effective for understanding trends. This method excels in handling complex data, providing a detailed view of the evolving dynamics. However, with a large number of variables, the chart may become complex and potentially cluttered, affecting visual clarity.

Failed Experiments:

Choropleth maps, initially used to show government spending on schemes by income group and country, are misleading because they suggest that larger areas mean higher healthcare spending. However, they don't reveal which country spends the most based on income level. To fix this, we've switched to Dot Distribution maps. In these maps, the dot size accurately represents government spending, giving a clearer picture. This change was made to focus on data measurement rather than the size of the location [3].

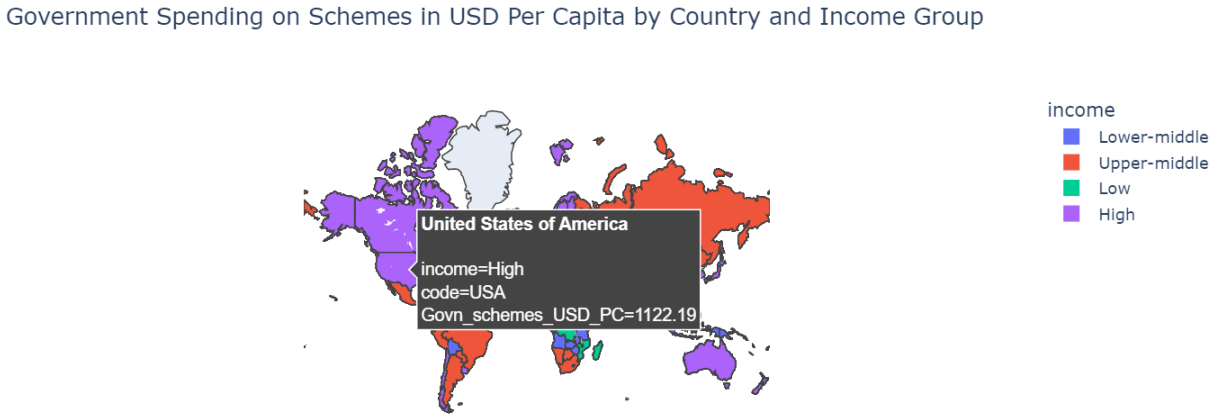

Fig. 4 Choropleth Map

Results and insights:

Research Question: Which are the top 10 countries from the dropdown that exhibit the highest healthcare expenditure in a selected year?

For the selected year: 2020

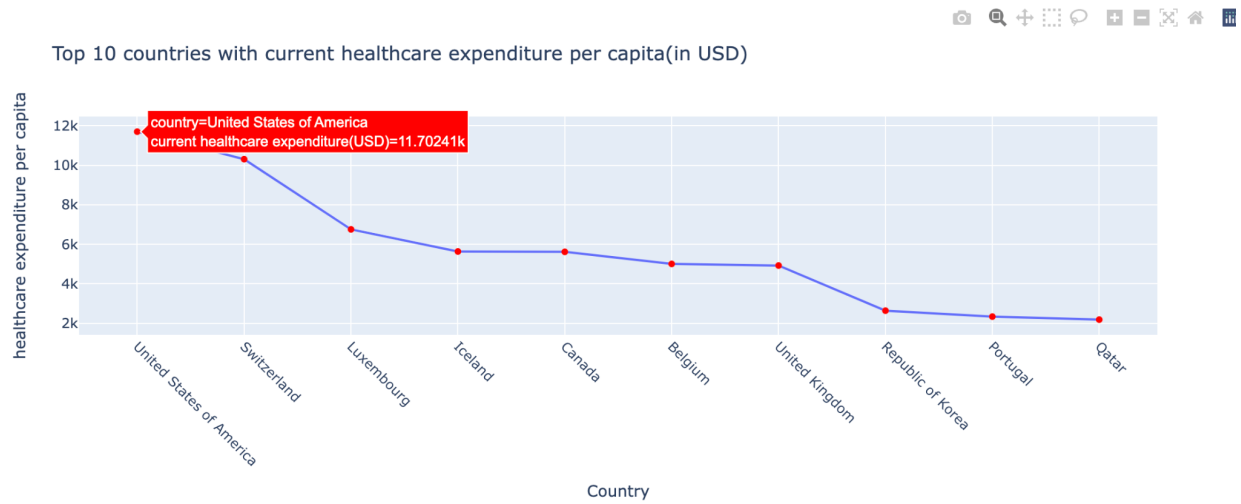

Fig.5 Line Plot

Insights:
For the selected year 2020:

- The top 10 countries with the highest current healthcare expenditure per capita in 2020 are: United States, Switzerland, Luxembourg, Iceland, Canada, Belgium, UK, Republic of Korea, Portugal, Qatar
- The country with the highest current healthcare expenditure per capita in 2020 is the United States with an expenditure of $11.70241K

- The country with the lowest current healthcare expenditure per capita in 2020 is Qatar with an expenditure of $2188.

Similarly, for each year between 2000 to 2020, we can find the top ten countries and the country with the highest & lowest healthcare expenditures.
Also, we can make a comparison of the top countries for each year, which can help coordinate Global health efforts, promote global health equity, foster cooperation, and monitor progress towards shared goals.

Research Question: How has current healthcare expenditure per capita changed in the United States compared to population growth?

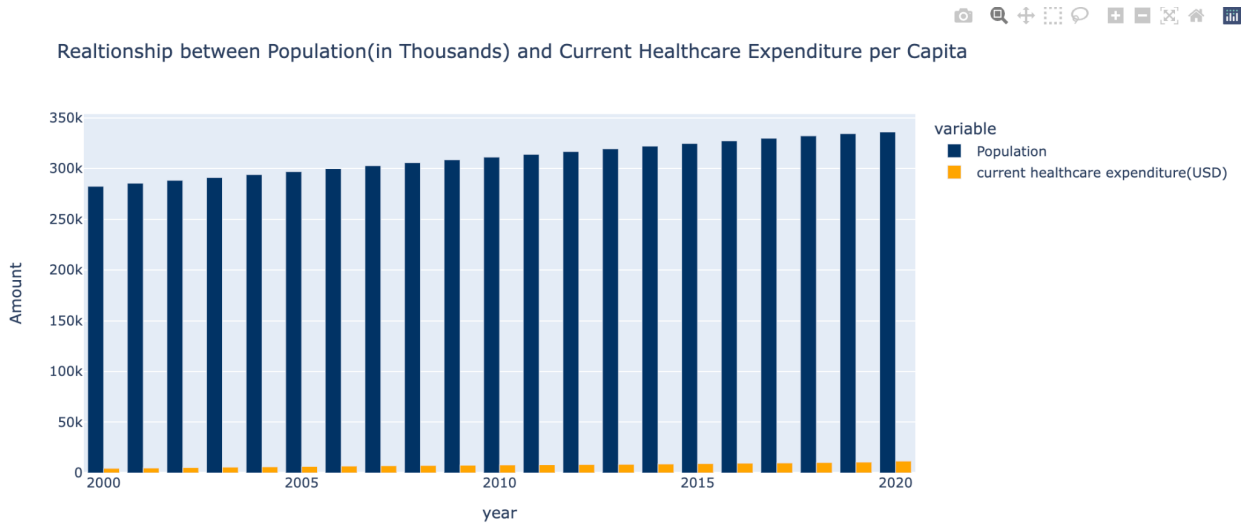

Fig.6 Bar Chart

Insights:
From this visualization:

- It shows that with the increasing population in the US, the current healthcare expenditure increases too from $4532 to $11.07K.
- There is a positive relationship between population and healthcare spending.

Hence, this visualization can help the USA with future budgeting, funding allocation, and policy adjustments with a growing population.

Research Question: What percent of the total current healthcare expenditure does the government and private sources contribute in the year 2020 for all the countries?

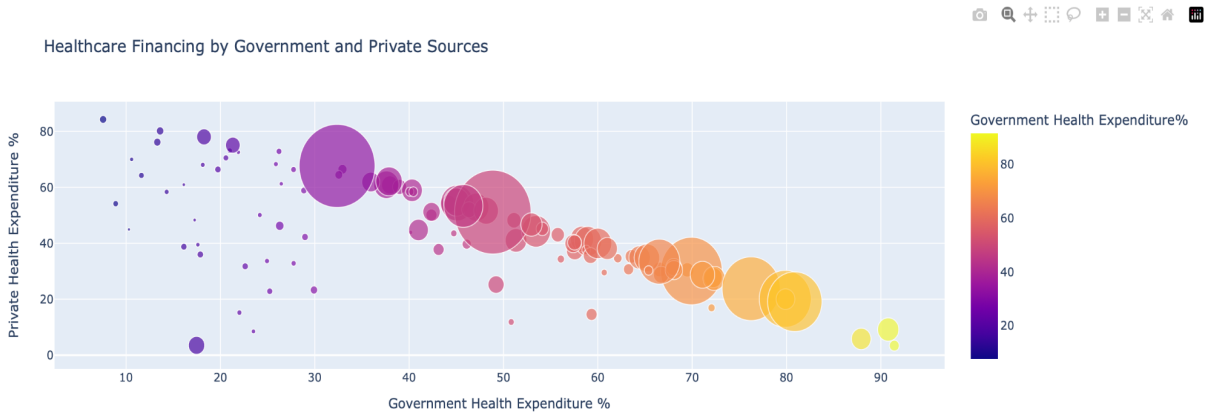

Fig. 7 Bubble Chart

Insights:

From this visualization:

- From right to left(violet to yellow color) the government healthcare expenditure % increases, Kiribati(91%) has the greatest government spendings of the total current expenditure and comoros(7.5%) has the lowest government contribution
- For countries with low government sources for healthcare like Comoros, might increase public health funding to reduce the burden on individuals
- There is a negative correlation between the two spendings because as the government spending increases the private spending decreases
- USA has the highest current healthcare spending per capita and has it has the largest bubble size, followed by Switzerland

Hence, this visualization will help to find the relationship between the two spendings, and how the spendings can be balanced to equalize the pressure in the future depending on the different policies the countries have.

Research Question: How much does the government spend on schemes based on Income level per capita?

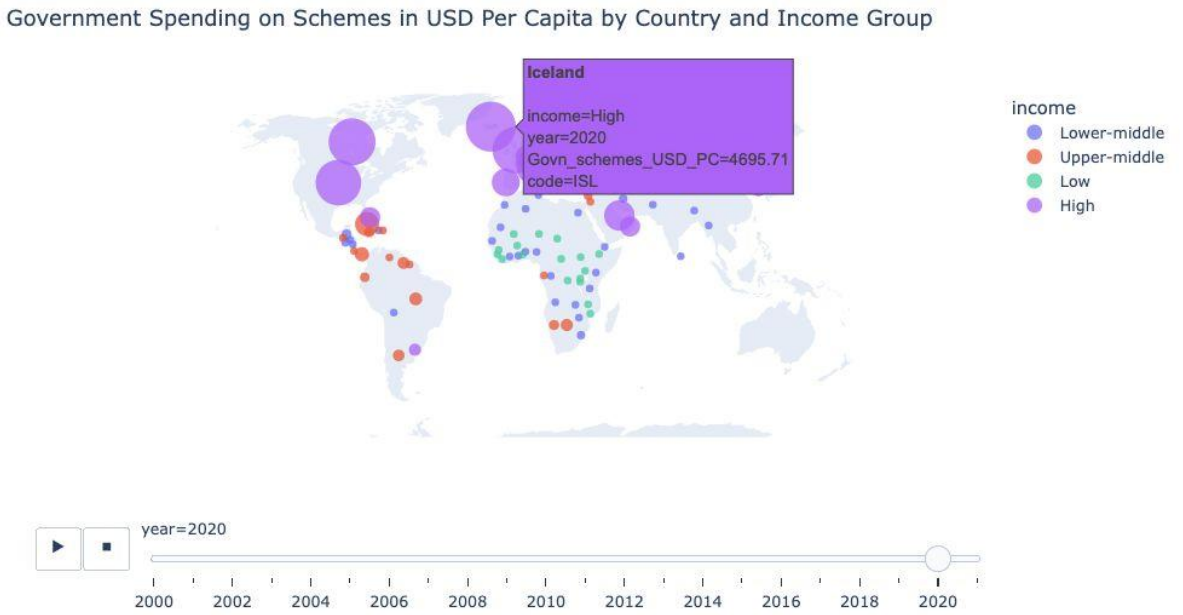

Fig. 8 Dot Visualization on Map

Insights:

From this visualization, it is clear that high-level income countries have a high rate of government scheme spending. As observed in fig.8, Iceland has the highest government spending for the year 2021, and it has first decreased in 2019 and then increased since 2018 [4], assuming the possible reasons. below:

- **Obesity rates are increasing:** Obesity rates among adults in Iceland have increased over the past decade.
- **Rise in number of Doctors and Nurses:** The number of doctors and nurses per population in Iceland has increased with 3.8 doctors per 1,000 population and 15.5 nurses per 1,000 population [5].

Research Question: How have health spending trends changed over the years in different parts of the world?

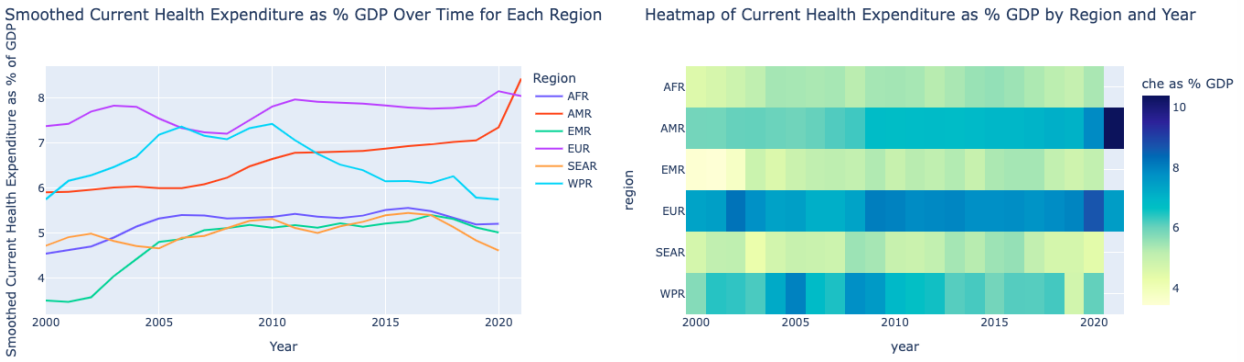

Fig. 9 Line Graph and HeatMap

- **Observation:** In 2019 and 2020, both America and Europe increased health spending by about 0.4% on the line graph.
  Insight: This uptick is likely a response to the impact of the COVID-19 pandemic [7][8], prompting nations to allocate more resources to healthcare to address the unprecedented health challenges during this period.
- **Observation:** In 2008, there's a clear drop in healthcare spending in Europe and some of the other regions.
  Insight: This decrease suggests a connection with the 2008 financial crisis [9], affecting economic indicators and potentially leading to reduced health spending during that year.
- **Observation:** In the heatmap, we notice Europe's consistent healthcare efforts and a sudden spike in America in 2020 and 2021. This indicates that Europe led in health spending until 2020, but in 2021, America took the lead with a significant increase.
  Insight: The shift from Europe to America in 2021 suggests possible changes in global health spending trends, influenced by responses to the ongoing pandemic, shifts in economic conditions, or evolving healthcare policies mainly due to the highest contributing country, the USA [10].

Research Question: How does health expenditure vary across income groups within different regions, and what changes have occurred from 2010 to 2020?

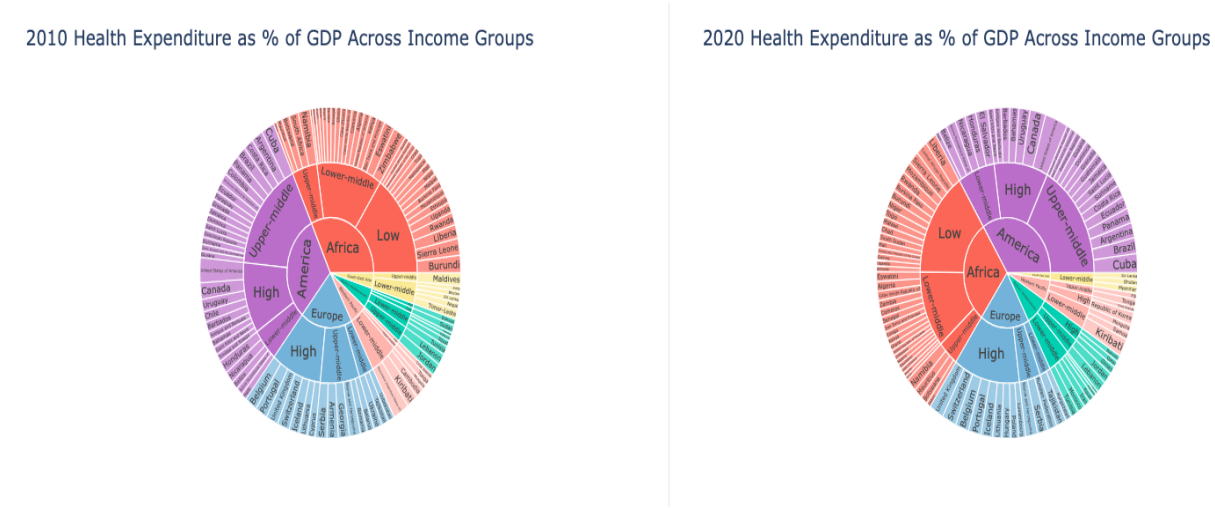

Fig 10. SunBurst Charts (2010,2020)

Insights:

- **Global Increase in Health Spending:** Global health spending has risen by a significant 24.5%, indicating a worldwide commitment to investing in healthcare. The average expenditure per person increased from 44.6 in 2010 to 55.6% in 2020.
- **Regional Priorities in the Americas:** America consistently prioritizes healthcare, with a notable 21.2% increase in high-income group spending. The USA led the region and the world with the highest expenditure, reaching 18.8%. This reflects a strong dedication to maintaining and improving healthcare services in the region.

- **Changes in Europe and Eastern Mediterranean:** Europe and Eastern Mediterranean exhibit dynamic changes. High-income group spending increased by 32.8%, but there are concerning decreases in 'Lower-middle' and 'Upper-middle' income groups (24.8% and 1.3% in Europe, 7.8% and 1.0% in Eastern Mediterranean). These shifts highlight the need for nuanced approaches to healthcare planning.
- **Challenges in South-East Asia:** South-East Asia faces challenges, especially in the 'Lower-middle' income group, experiencing a significant 39.2% decrease in health expenditure. This signals potential issues in healthcare accessibility and affordability that require attention.
- **Fluctuations in Western Pacific:** The Western Pacific shows fluctuations, notably with a 41.6% decrease in the 'High' income group. This indicates a need for a closer examination of healthcare resource management and potential shifts in regional priorities.

Research Question: How has the evolving relationship between purchasing power parity and exchange rates expenses worldwide since the year 2000 impacted global economic dynamics?

Fig.11 Spider Chart

Insights:

When examining purchasing power parity, exchange rates, and out-of-pocket expenses worldwide over the years, we aggregated the sums for each variable, grouping them by year. The spider chart illustrates a direct correlation between purchasing power parity and exchange rates, indicating that as purchasing power parity increases, so does the exchange rate. Both of these variables have exhibited an upward trend since the year 2000.

Research Question: How does the hierarchy and proportion of healthcare financing sources vary across different countries?

Fig.12 TreeMap

Insights:

Upon visualizing the TreeMap, notable patterns emerge in the hierarchy and proportion of healthcare financing sources across select countries. The United States, positioned at the top, exhibits the largest rectangle, reflecting its substantial total healthcare expenditure. Following closely are the United Kingdom, Canada, Brazil, and India, each represented by rectangles indicative of their respective healthcare expenditures.

Within each country's rectangle, the distribution of smaller rectangles signifies the diverse financing sources contributing to the overall healthcare financing namely:

- Total Health Expenditure, Government Schemes and compulsory Contributions, Government Schemes
- Voluntary Health Payment Schemes
- Voluntary Health Insurance Schemes
- NPISH Financing Schemes (including development agencies)
- Household Out-of-Pocket Payment

This visualization enables a comparative analysis of the financing structures among these nations. The size disparities in the rectangles shed light on the varying magnitudes of healthcare expenditures, while the arrangement and proportions of the smaller rectangles provide insights into the relative contributions of different financing sources within each country's healthcare system.

Conclusion:

In conclusion, we embarked on a vital mission, employing innovative data visualization techniques to address healthcare inequalities. By revealing trends and gaps in healthcare accessibility across demographics, this project actively contributes to the pursuit of efficient, enduring, and equitable global healthcare systems. Through meticulous analysis of healthcare expenditure data spanning 20 years, critical gaps in existing visualizations are addressed, establishing a new benchmark for effective communication and comprehension of healthcare economics. The insights gleaned are pivotal for guiding informed policy decisions and propelling the mission for accessible and equitable healthcare for all.

Future Work:

Looking ahead, our strategic focus involves integrating additional health economics data, including insights into cost-effectiveness and resource allocation, connecting dynamically to live data sources. This approach aims to offer a real-time and comprehensive understanding of the economic factors shaping healthcare systems, providing timely insights for informed policy decisions. Simultaneously, we are committed to enhancing user engagement by developing a more user-friendly web application and a unified dashboard, ensuring broader accessibility and usability. By combining the integration of live health economics data with user-centric enhancements, our goal is to make a meaningful contribution to the realization of universally accessible and equitable healthcare.

Links to project:

Github link: https://github.com/shrutihouji/Health-expenditure-analysis
Web application link: https://health-expenditure-analysis.onrender.com/

References:

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2. https://apps.who.int/nha/database/Select/Indicators/en
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