Inflation: The Great Balancing Act

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Introduction

Inflation is a complex and important economic phenomenon that can have a significant impact on individuals, businesses, and countries. It drives investment decisions and helps formulate a country's fiscal policies. It's a subject that is as deep as it is wide, and provides a great scope for data analysis. We selected this subject due to our mutual interest in economics and our desire to learn more about inflation rates, which have been in the news lately for a variety of reasons.

The goal of this analysis is to investigate the underlying causes and effects of inflation rates observed in countries worldwide.

We will be considering the following indices for the purpose of this exploration:

Inflation:
Inflation is the rate at which the general price level of goods and services in an economy rises over time. It is usually expressed as a percentage. Inflation erodes the purchasing power of a currency, meaning that over time, the same amount of money can buy fewer goods and services. Central banks often aim to manage inflation within a target range to maintain price stability.

GDP:
GDP stands for Gross Domestic Product and is a measure of the economic performance and output of a country. Since this data is in Local Currency, we will be conducting all our analysis on the GDP growth rate rather than the absolute number.

Debt Value:
Debt Value refers to the total amount of debt that a country or entity owes to external creditors or lenders. It represents the accumulated financial obligations that need to be repaid over time, often with interest. We will be using the 'Debt as a share of GDP indicator' for our analysis.

Broad Money:
Broad Money, often represented as M2 or M3, is a measure of the total money supply in an economy. Broad money includes physical currency (notes and coins) in circulation, as well as various types of deposits, such as checking accounts and savings accounts. It represents the overall liquidity and financial assets available within an economy. Since this data is in Local Currency, we will be conducting all our analysis on the Broad Money growth and growth rate rather than the absolute number.

Our approach will be top-down. We will begin with a high-level look at the correlations between inflation and other indices. We'll be specially looking at the high inflation levels as an area of focus. Finally, we will cluster them by a temporal or spatial commonality (such as by region, similar economic conditions at a given time, or a world event) to derive interesting economic insights.

Data Sources

All data sources are in CSV, and are obtained using a download link on the website.

File	Inflation Rate File	Debt Value File	GDP File	Broad Money File	Supplementary File
Source	World Bank	UNCTAD	World Bank	World Bank	World Bank
Description	Annual Consumer Price Inflation Rate	Annual Debt Value (as a share of GDP)	Annual GDP Value (in local currency)	Annual Broad Money Value in local currency	Additional data about the country's income group and region
Year	1960-2022	2010-2022	1960-2022	1960-2022	1960-2022

Data Manipulation

Pre-Processing Steps

- The data pre-1990 is very sparse. Thus, after **loading** our CSVs we **filter** our data to include only years between 1990 and 2022, as that is the time span our analysis is limited to.
- The debt data contains different indicators such as 'Debt as a share of GDP' and 'Debt per capita in USD'. We retain only those rows that have 'Debt as a share of GDP' as an indicator.
- We **convert** the year to int datatype so that we can plot the years in order.
- We create a **function** to return a cleaned dataframe by doing the following:
  - The data obtained from the world bank is in wide form. We then use **pd.melt** to convert it to long form (having two new columns called 'Year' and a column with the index name)
  - We then calculate the **growth** and **growth rate** for each index. To do so, we first **replace all zeroes** with np.nan to avoid the divide by zero error.
  - We then add a new column called 'Previous Year Value' by using the **shift(1)** method.
    - Growth= (Current Year's Value) - (Previous Year's Value)
    - Growth Rate= (Growth) / (Previous Year's Value)
    - We **round** both values to the third decimal place
- Since our debt data is from another source, we **replace** several country names to match the names from the World Bank data.
- We also **rename** the country column in the debt data for the same reason.
- We finally **merge** all 5 data sources (gdp, debt, broad_money, inflation, common) by using an outer join into a dataframe called **merged_data**. This will be our primary dataframe for all following analyses.
- Since debt is represented as a share of GDP, we multiply it by the GDP data we have obtained from World Bank to get the absolute debt value. After this, we calculate the debt growth and debt growth rate in the same manner as mentioned previously.

Handling Missing Values

- We tried three ways to handle missing values:
  - Replace all Nan values with zero.
  - To maintain the temporal nature of the data, we substituted all missing values with the average previous and next available value.
  - Maintain the Nan values as they are.
- We finalized the last method as the first two were becoming the cause of specious correlations.
- Choosing the right method to handle missing values and recognizing which method yielded the most accurate analyses was tedious and challenging.

Decoding Inflation Trends

Defining the baseline

We divide inflation levels into the following categories:

- Healthy inflation: Values between 0 and 12
- High Inflation: Values between 12 and 50
- Hyper inflation: Values greater than 50

- For the years from 1990 till 2022, majority of healthy inflation levels lie between 1 and 7 percent, with the mean value of inflation at 4%.
- Values less than 0 (i.e., deflation) lie outside the scope of our analysis.

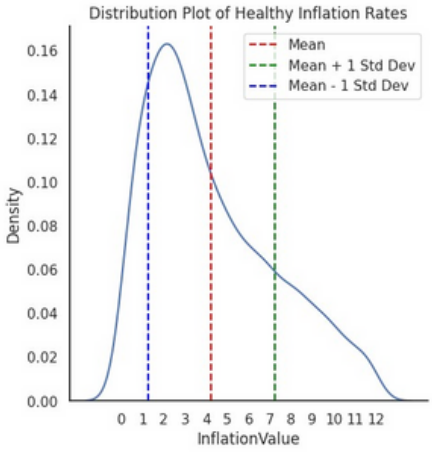

Fig 0: Healthy Inflation Density Plot

How are the indices correlated?

If we look at the heatmap in Fig 1, we see two positive correlations arising for periods of high inflation. They are between:

- Inflation and broad money growth rate
- Broad money growth and debt growth

Most of the causes of high inflation are wars, and political or economic problems. Governments borrow excessively during such periods. They then print excessive amounts of money to cope with these debts, deprecating the currency value. As value deprecates, people lose confidence in the currency and act precautionarily in anticipation of a crisis, thus increasing inflation levels further.
High inflation drives up prices of goods, thus driving up the money in circulation (broad money). While we do not know if there is causation between the two, we can say that the money growth can be a good metric to predict inflation levels.

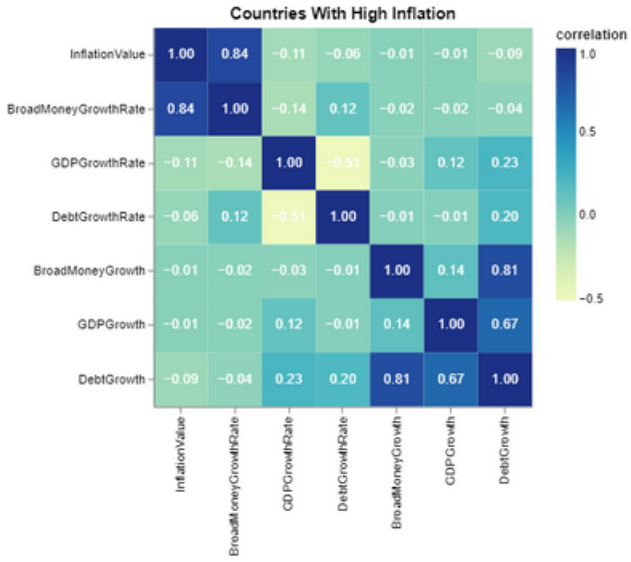

Fig 1: Correlation Heatmap

Extending the study of the same correlation at the regional level, we find that there is a high correlation between inflation levels and the broad money growth rate across several regions (see Fig. 2). This correlation applies to all inflation levels.

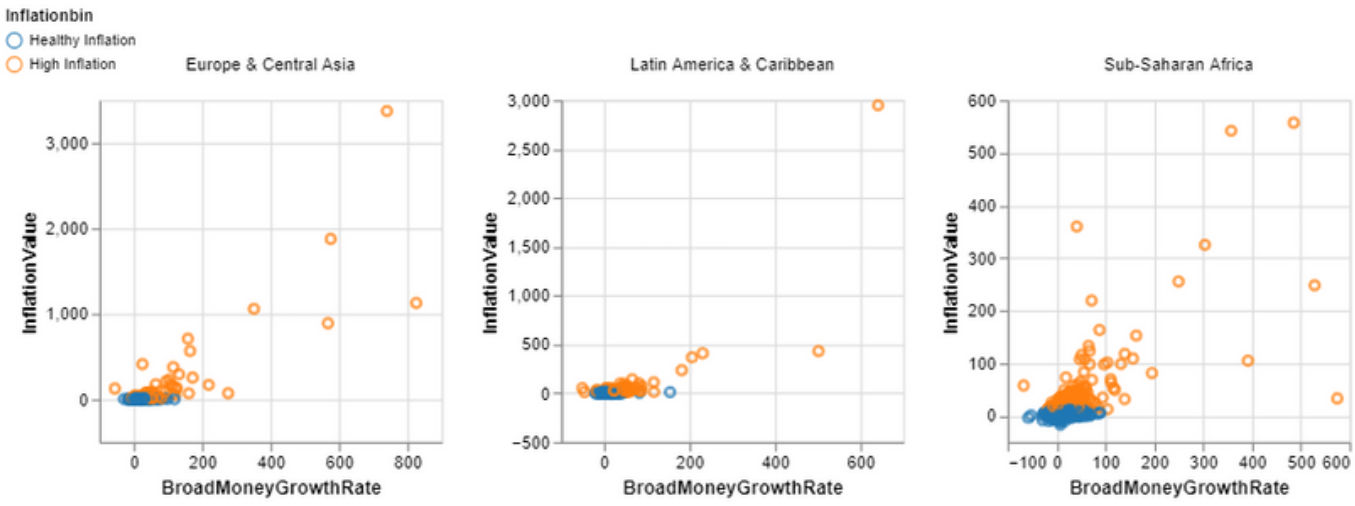

Fig 2: Regional Scatter Plot for Broad Money vs Inflation in High Correlation Regions

A closer look at regional level correlations

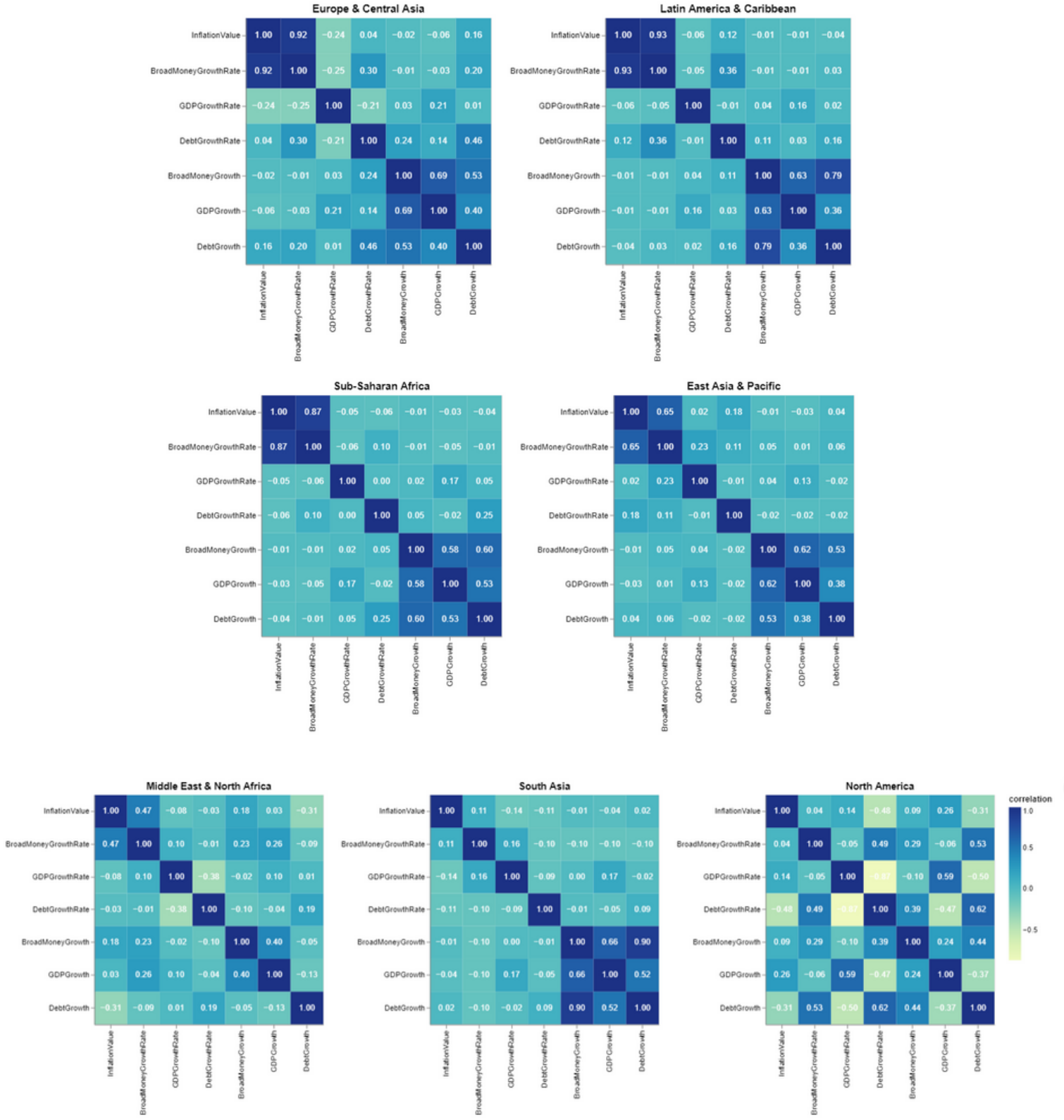

Fig 2.1: Correlation Plot by Region

Observations

- We observe that a region with higher average inflation value, such as Europe & Central Asia, Latin America & Caribbean, and Sub-Saharan Africa (see highlights in Fig 2.2) displays high correlation between broad money growth rate and inflation, and mild to high correlation between debt growth and broad money growth. Both echo our findings on the previous page.

Region	Mean Inflation Rate
East Asia & Pacific	5.37
Europe & Central Asia	23.36
Latin America & Caribbean	24.47
Middle East & North Africa	8.43
North America	2.40
South Asia	7.10
Sub-Saharan Africa	45.73

Fig 2.2: Mean Inflation Rates by Region

Have we been complaining too much about the inflation levels rising?

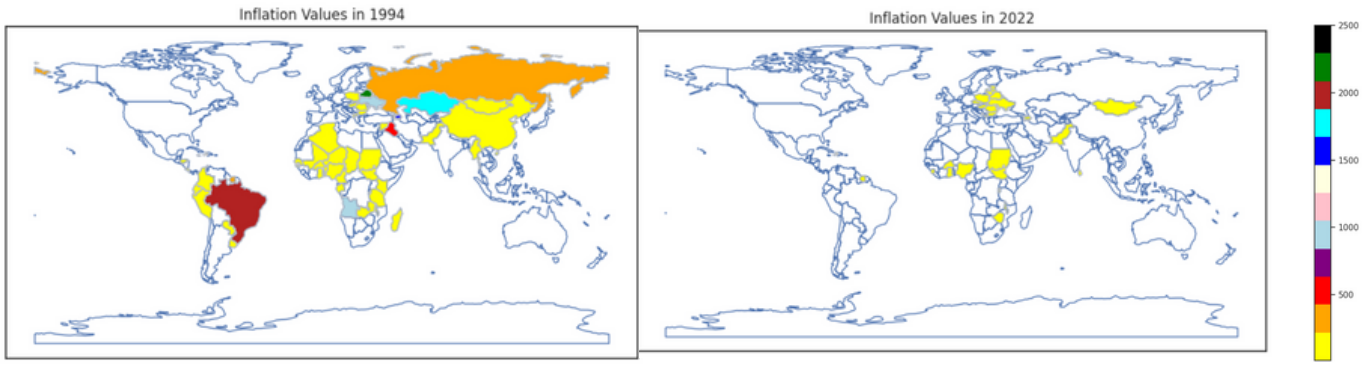

Fig 3: Inflation Values in 1994 and 2022

Yes!
While we constantly read of inflation levels rising in the news, the data says otherwise. We have little to no occurrences of hyper inflation post 2010 (refer Fig. 3). Even the number of countries having high inflation have reduced. The concentration of high inflation countries now largely lies limited to the African subcontinent. We suspect that this has something to do with sporadic civil wars in the region, as well as China lending huge amounts to those countries.

Inflation through the years

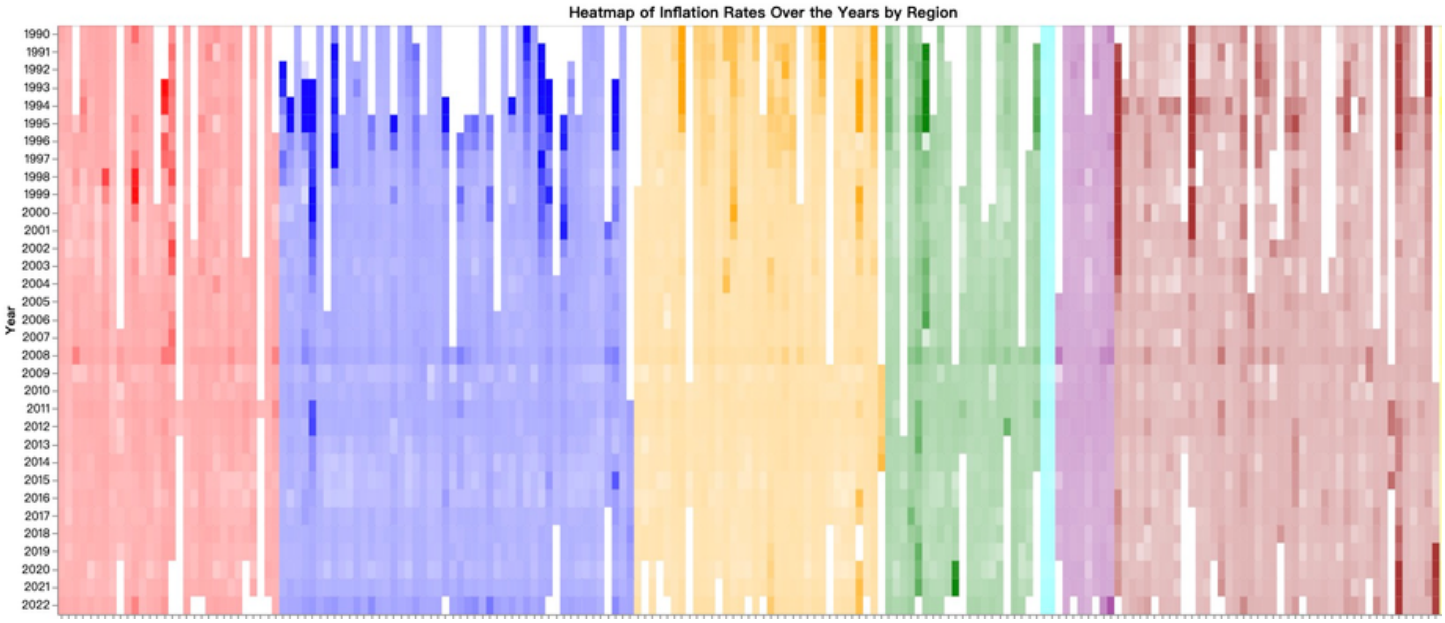

Fig 4: Opacity Heatmap

Observations:

- In Fig 4, we see that USA and Canada have consistently maintained healthy inflation levels over the last 30 years. However, interestingly, both the countries' inflations are at an all time high as of 2022.
- Barring a handful countries, Sub Saharan Africa has consistently had high to very high inflation levels.
- Sri Lanka's inflation rate rose dramatically in 2022 with the onset of the crisis they faced.
- Iraq shows high inflation levels all through the periods of war.

- About 55% of countries in Europe and Central Asia have experienced hyper inflation (>50%) at some point. We notice a concentration of high inflation levels in the region around the early 1990s.
- On digging deeper, it is clear that the early 1990s were a period of major flux for USSR countries in Europe and Central Asia. USSR fell in 1991, and it was a period of great change. There were a lot of new countries formed during this period, which creates major fluctuations in inflation levels.

Effect of the Fall of USSR on Inflation and Other Indices

USSR dissolved in December, 1991. For our analysis, we consider 15 nations that were once part of USSR (including Russia).
In Fig 5, we see that in the 5 years immediately following the split, there is a very high correlation of inflation with the broad money growth rate. This correlation reduces post 1997.
Over time, some post-Soviet countries may have implemented policies to stabilize their economies, which could include controlling the money supply and inflation. As economies stabilize and institutions strengthen, the relationship between broad money and inflation may weaken.

(We acknowledge the limitations of comparing a span of 5 years against a longer span of 20+ years)

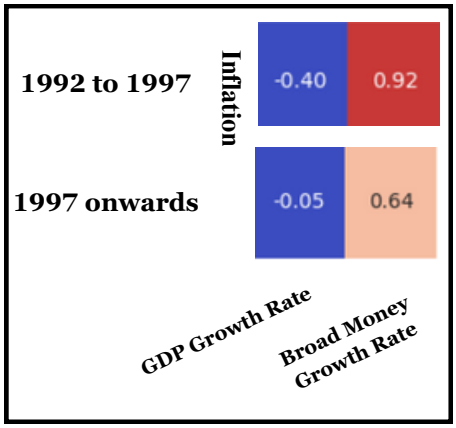

Fig 5: Correlation Plot for Inflation Values in USSR region

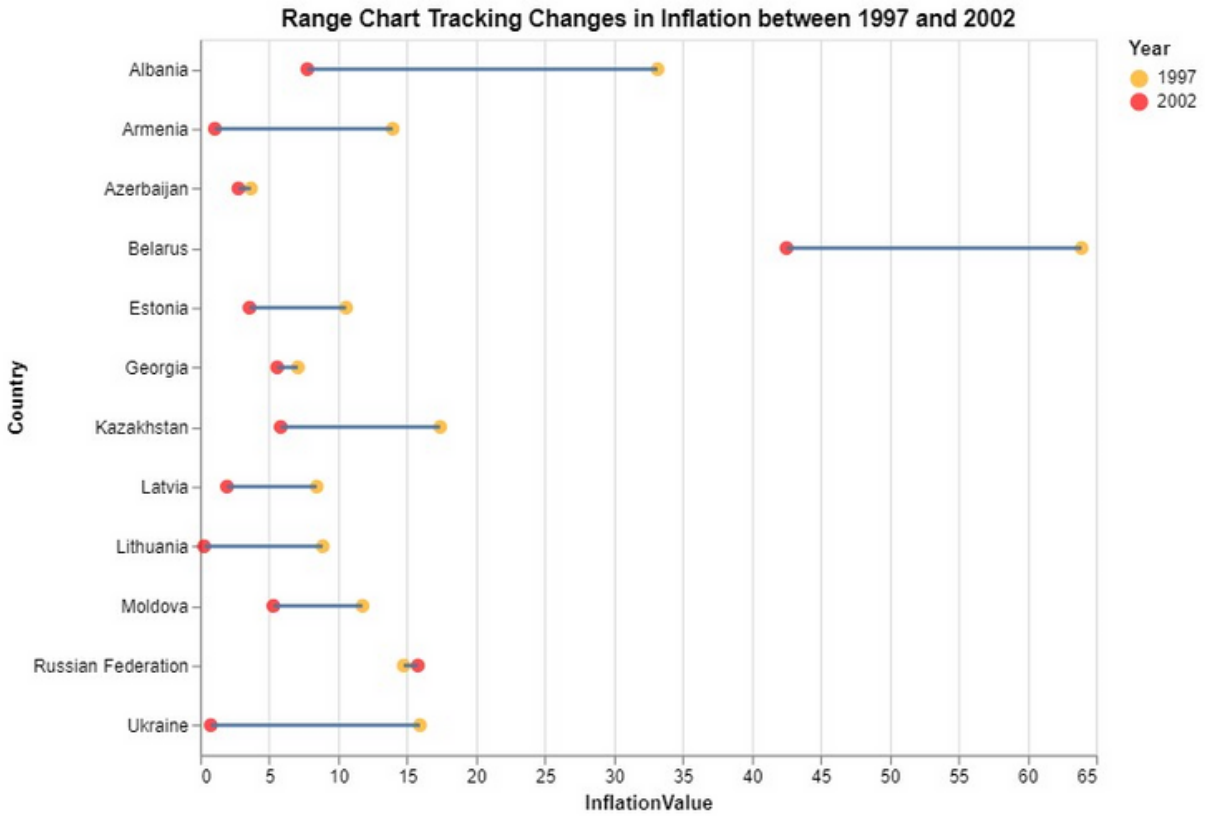

Fig 6: Dumbbell Plot

We plot a dumbbell chart of inflation values in 1997 and 2002 (see Fig 6). We choose 1997 due to limitations in data completeness prior to the year.
2002 marks 10 years since the split. We see that barring Belarus and Russian Federation, all other countries brought inflation under control within the decade.

- However, it is worth noting that Belarus's inflation level was much higher than the other countries' in 1997, so it is understandable if it takes longer to bring under control.
- In Russia's case, its inability to repay foreign debt led to the devaluation of the Ruble. Russia borrowed heavily for domestic investments, and when it struggled to repay these debts, it faced economic challenges. Russia provided assistance to countries it had parted by heavily importing from them without checks on whether it had enough money to pay them back. All of this caused high inflation levels in the region. (Here, we would've liked to further examine the debt levels but could not due to the unavailability of data pre-2010)

When America sneezes, the world catches a cold

We wanted to know if this adage holds true.
Limiting our study to inflation, we calculated the correlation of USA's Inflation Value with all other countries' GDP Growth Rate, Inflation Value and Debt Growth Rate.
We find that inflation values worldwide are indeed highly correlated to USA's inflation values.

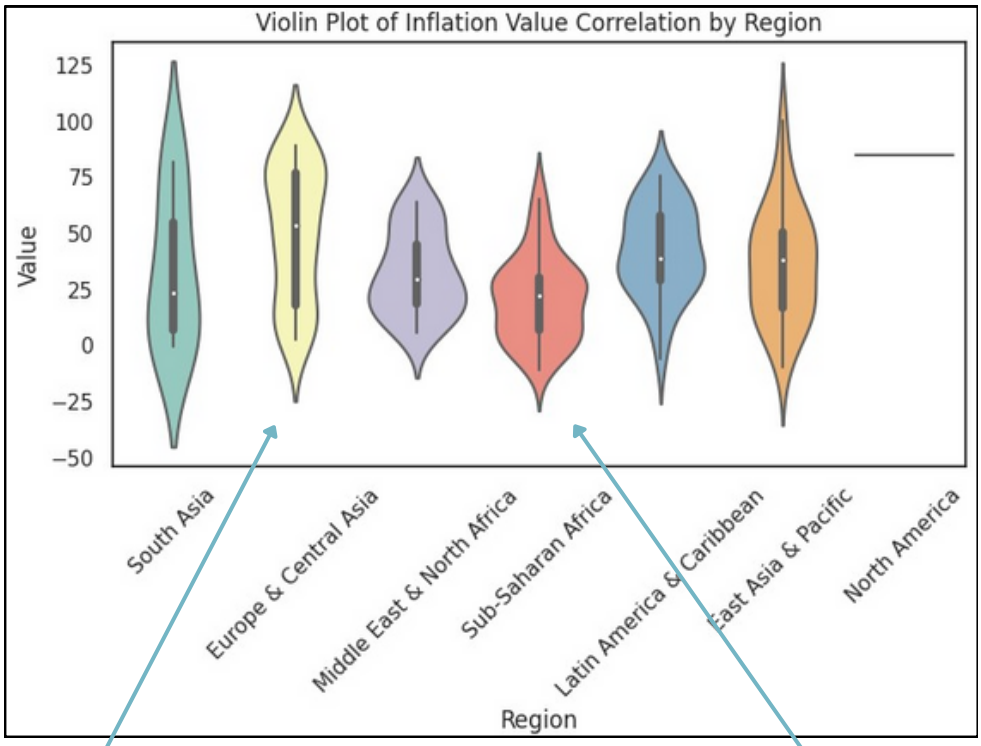

Fig 7: Violin Plot Demonstrating Regional Dependence on USA's Inflation Levels

Europe & Central Asia has the highest correlation with USA's inflation values

Sub-Saharan Africa has the lowest median value, impliyng the least correlation with USA's inflation values.

Observations

- Inflation values in Canada (only other country in North America) and Europe and Central Asia are most correlated to the inflation levels in USA.
- Overall, majority of countries in the African region aren't correlated to the US Economy, and function quite independently. In African countries, agriculture and natural resource extraction may play a dominant role in their economies, and their economic condition may be influenced more by global commodity prices and regional dynamics than by the US economy. An additional reason could be the war conditions that have persisted across the region as well as the debt that the region largely owes to China.
- India's economy is driven more by domestic factors than an external country. Therefore, its correlation levels for any of the indices are rather low.

Exploration of Inflation Rates during 2 Major World Events

We plot the GDP growth rate and the Inflation values over the years using a line and area chart.
The line chart demonstrates the mean value in that year, while the area around the line represents the range between the maximum and minimum values of the index in that year.
(For reference, see Fig 8 and Fig 9.)

The purple dotted line represents two major world events:

- Global financial crisis in 2008
- Covid-19 pandemic in 2020

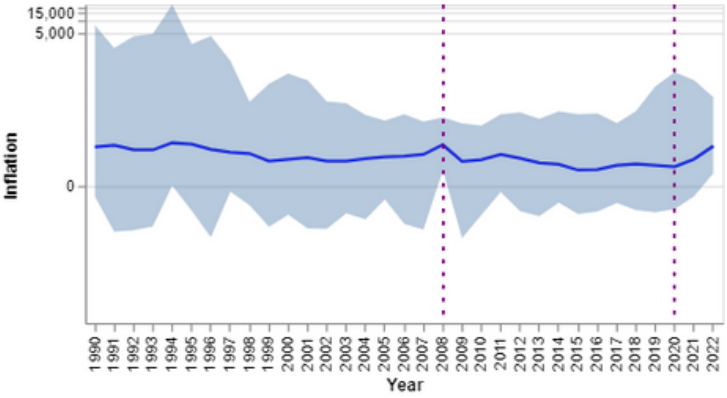

Fig 8: Line and Area Chart of Inflation Through the Years on Symlog Scale

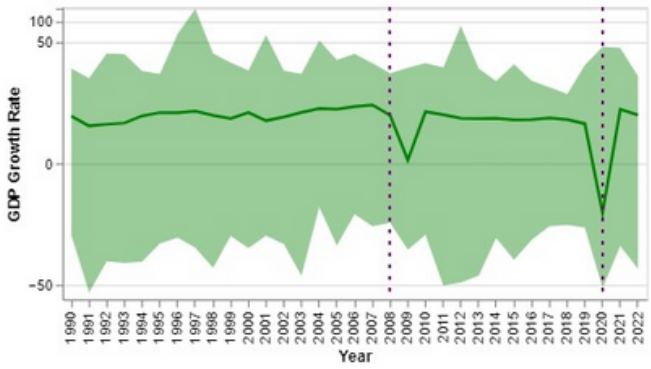

Fig 9: Line and Area Chart of GDP Growth Rate Through the Years on Symlog Scale

- **Global Financial Crisis:**
    - In 2008, many countries experienced a period of inflation driven by several factors, one of which is that many central banks pursued expansionary monetary policies in the years leading up to the financial crisis, the increment of money supply contributed to inflation.
    - Then the housing bubble burst. The collapse of major financial institutions in 2008 triggered a severe global financial crisis. This led to a sharp contraction in economic activity in 2009, decreased consumer and business spending, and reduced demand for goods and services. As demand plummeted, business was forced to lower prices to attract customers, contributing to deflation.
    - In 2008, before the full impact of the global financial crisis, many countries experienced economic growth. The contraction in global trade was a major factor contributing to the decline in GDP. As consumer and business spending decreased worldwide, demand for imports dropped, causing a sharp decline in international trade.
- **Covid 19:**
    - Conversely, the inflation rates massively dropped during the peak of the pandemic in 2020, and has steadily risen since in the last 2 years. As an after-effect of the pandemic, there was a drop in consumer demand for goods, travel and other services. People spent only on essential items only. Most countries also implemented economic policies to support their economies during the pandemic. Once the world started opening up, the world witnessed phenomenon such as revenge travel and a reopening of economies. However, supply chain disruptions continued, and demand failed to be met. This increased market prices and thus, increased inflation levels. That, along with the stimulus packages governments released to boost the economies have caused a sudden rise.
    - There was a sharp rise in GDP Growth rate in 2021, when the economies bounced back post the Covid-19 crises. All but low income countries then saw a kind of adjustment (as evidenced by the decline) of GDP growth, where the GDP Growth Rate reduced in 2022.

A Study of Resilience

Is a sharp GDP growth rate always a good thing?
We first hand pick a few countries that have consistently maintained inflation values within the permissible levels and have had very low levels of variance year on year. These countries are categorized as countries having a 'Stable Economy'.
We then contrast these countries with other countries with high inflation values. Then we investigate their inflation variance and GDP growth rate variance.

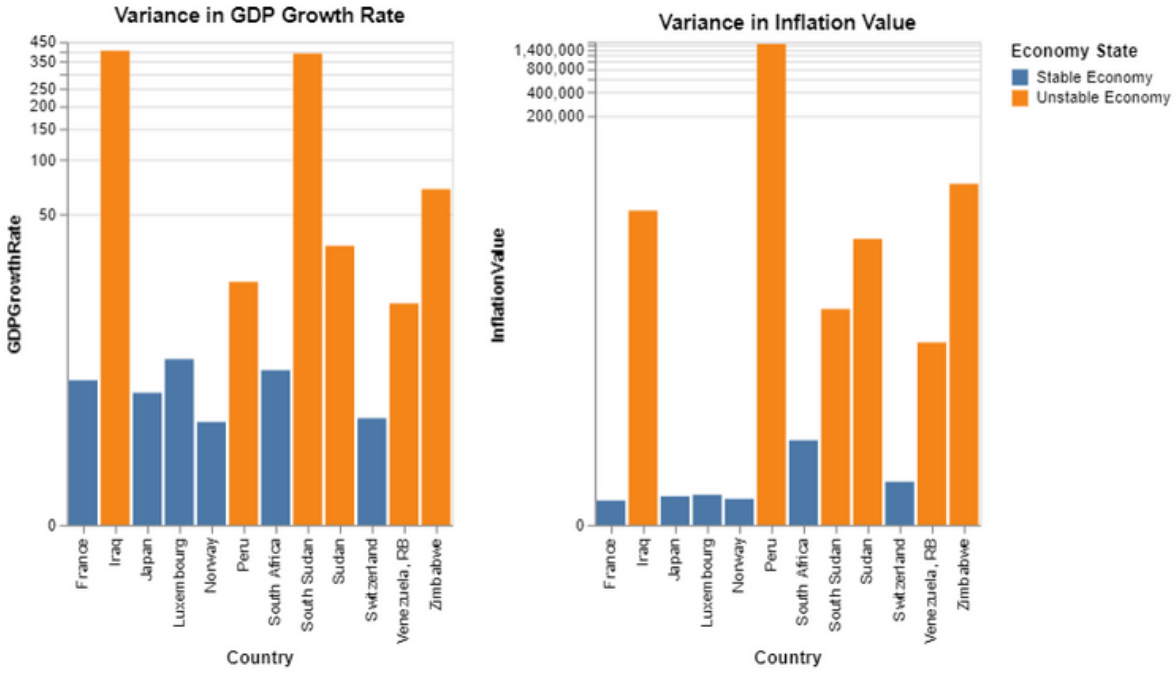

Fig 10: Variance in GDP Growth Rate and Inflation Value on Symlog Scale

Observations

- The hallmark of a steady and resilient economy (having manageable inflation levels) is one where the variance of GDP growth rate is within a limited range of 0 to 7 percent.
- While the fact that stable economies display low variance in inflation rates is intuitive, it is noteworthy that they also display low levels of variance of GDP growth rates.
- Therefore, a massive GDP growth rate doesn't necessarily imply that the country has a healthy economic condition (For example, Iraq reached a shocking level of 54% growth rate in one year. However, it is by no means a stable economy).

Conclusion

- We have found that inflation values world over have been declining over time.
- One of the first indices that gets affected at the onset of a crisis or war is the inflation value.
- Inflation is highly correlated with broad money growth during periods of high inflation.
- An economy having a controlled and healthy inflation level also displays low variance in GDP growth rate.

Future Scope and Limitations

- UNCTAD only had debt data from 2010. This is a small time span as compared to the data we had for other indices from 1990. We would've liked to find other sources for this data to fill in the missing gaps.
- We are aware that a lot of effects may be seen over time, and not within the same year. We have not accounted for the indices being lagging indicators.
- We would want to cluster countries having similar index values together, and track their changes over a ten year span.
- During our research, we found that the interest rates have great impact on the inflation levels, and would like to expand our analysis to include this.
- We could forecast the inflation values by building a time series or regression model.

Statement of Work

We connected for two to three hours per week to discuss our progress. There was clear communication and responsibility sharing between us.

While we worked on all parts together, this was broadly the distribution of tasks:

- Anandita:
  - Deep dive into different temporal scenarios (Covid 19, pandemic, Soviet split, effect of US's inflation value)
  - Writing generalized functions
  - Report writing
- Irene:
  - Data cleaning and pre processing
  - Deep dive into and exploration of regional trends
  - Deep dive into and exploration of country level trends
- Both of us shared the responsibility of writing code, suggesting changes and providing feedback wherever necessary.
- Throughout the project, Irene ensured that our findings aligned with general economics fundamentals and Anandita suggested alternative methodologies to explore the effects.

Our major learning from this collaboration was the need to converge our data cleaning processes early on to avoid specious/conflicting correlations.

Links to Code and Data

- Code: Link to Google Colab
- Datasets: Google Drive link to data

References

- Is High Debt Constraining Monetary Policy?
- In the US and over, inflation is high and getting higher
- Russian Flu
- Benefits of Inflation
- Hyperinflation in Russia
- Relationship between public debt and inflation in developing countries
- Which countries have lower inflation?
- Trade relations between Africa and America