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Economic Crises in African Countries: A Comprehensive Data Visualization Report

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DATA VISUALIZATION ASSESSMENT 2

1. Introduction

In a world where achieving a stable economy poses challenges, understanding economic crises becomes crucial. This report delves into the African continent, rich in history but grappling with economic hurdles. Leveraging the "African Crises" dataset from Kaggle, a platform for predictive modelling and analytics competitions, we examine the patterns and impacts of economic crises across different African nations over time.

This dataset, spanning from 1860 to 2014, captures diverse economic and financial crises in 13 African countries. It provides indicators for various crisis types and essential economic metrics, including government debt defaults, exchange rates to USD, inflation, and independence status. The report aims to analyze these crises, focusing on comprehending the economic and financial stability of African nations throughout history.

2. Dataset Exploration

The exploratory data analysis (EDA) performed in R Studio Markdown revealed several key aspects of the dataset:

a. Summary Statistics:

The summary statistics for the African Crises dataset reveal that it contains data ranging from 1860 to 2014 across 1059 entries. Key numerical indicators such as exchange rates and inflation show a wide range, with some extreme values suggesting occurrences of hyperinflation and significant exchange rate volatility. Binary indicators for various types of crises (systemic, domestic debt default, sovereign external debt default, currency crises, and inflation crises) suggest these events are relatively infrequent. Most of the dataset entries correspond to periods when the countries were independent. The dataset includes a mix of categorical and numerical data, with variables indicating the presence of crises and economic conditions within African countries.

case	cc3	country	year	systemic_crisis	exch_usd
Min. : 1.00	Length:1059	Length:1059	Min. :1860	Min. :0.00000	Min. : 0.0000
1st Qu.:15.00	Class :character	Class :character	1st Qu.:1951	1st Qu.:0.00000	1st Qu.: 0.1954
Median :38.00	Mode :character	Mode :character	Median :1973	Median :0.00000	Median : 0.8684
Mean :35.61			Mean :1968	Mean :0.07743	Mean : 43.1408
3rd Qu.:56.00			3rd Qu.:1994	3rd Qu.:0.00000	3rd Qu.: 8.4628
Max. :70.00			Max. :2014	Max. :1.00000	Max. :744.3061
domestic_debt_in_default	sovereign_external_debt_default	gdp_weighted_default	inflation_annual_cpi		
Min. :0.00000	Min. :0.000	Min. :0.000000	Min. : -29		
1st Qu.:0.00000	1st Qu.:0.000	1st Qu.:0.000000	1st Qu.: 2		
Median :0.00000	Median :0.000	Median :0.000000	Median : 6		
Mean :0.03966	Mean :0.153	Mean :0.006402	Mean : 20849		
3rd Qu.:0.00000	3rd Qu.:0.000	3rd Qu.:0.000000	3rd Qu.: 12		
Max. :1.00000	Max. :1.000	Max. :0.400000	Max. :21989695		
independence	currency_crises	inflation_crises	banking_crisis		
Min. :0.0000	Min. :0.0000	Min. :0.0000	Length:1059		
1st Qu.:1.0000	1st Qu.:0.0000	1st Qu.:0.0000	Class :character		
Median :1.0000	Median :0.0000	Median :0.0000	Mode :character		
Mean :0.7762	Mean :0.1322	Mean :0.1294			
3rd Qu.:1.0000	3rd Qu.:0.0000	3rd Qu.:0.0000			
Max. :1.0000	Max. :2.0000	Max. :1.0000			

b. Data Structure:

The dataset is structured with each row representing a year-country combination and columns for different economic indicators and crisis types.

c. Data Types:

Primarily consists of numerical and categorical data, with countries as categorical variables and indicators like exchange rates, domestic debt default, GDP default, inflation cpi and crisis occurrences as numerical variables.

DATA VISUALIZATION ASSESSMENT 2

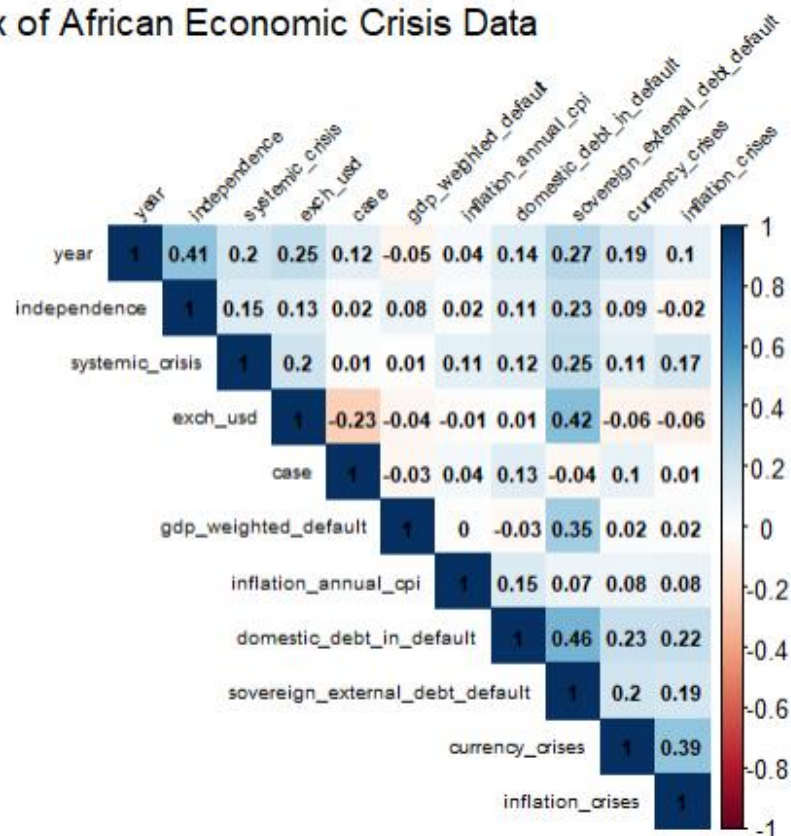
d. Missing Values:

There are no missing values in the dataset. This was computed in R Studio, and it returned zero values.

e. Correlation Matrix:

The correlation matrix visually and numerically displays relationships between numerical variables. Values close to 1 mean a strong positive correlation, close to -1 show a strong negative correlation, and close to 0 indicate weak or no relationship. Colours like blue (positive) or red (negative) signify correlation strength and direction. Presently, no strong correlations exist, but weak positive correlations are noted, such as between exchange rates and external debt and domestic debt and sovereign external debt. It is worthy to note that correlation does not mean causation; additional analysis is required for causal implications.

Correlation Matrix of African Economic Crisis Data

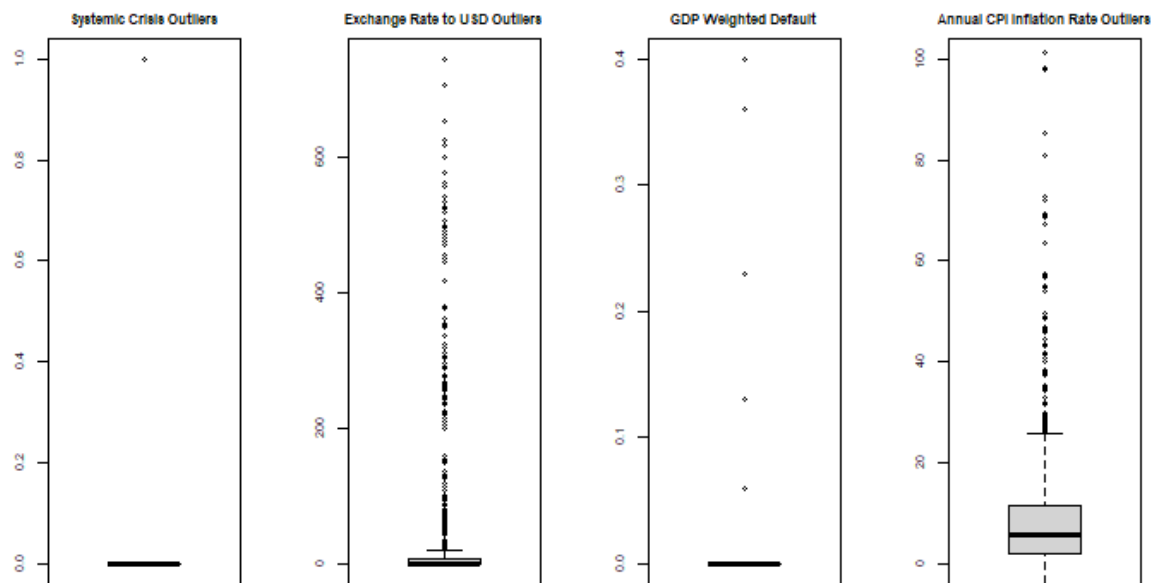


f. Outliers

Outliers are extreme values that are far from the mean of the dataset which could affect the analysis of the dataset (Engineering Statistics Handbook, 2019). The box plot for exchange rate and annual CPI inflation reveals a large number of outliers indicating significant variations in exchange rates which could represent periods of significant currency devaluation or appreciation and periods of extremely high inflation in some observations.

The outliers were kept in the dataset, because this report focuses on economic crises and exchange rates, therefore outliers become a key data point that can provide insight into extreme economic conditions.

Boxplot for Numerical Variables to Visualize Outliers



Using the EDA, we have been able to understand the dataset's structure, data types, missing values, summary statistics, correlation and outliers in the dataset. This preliminary analysis revealed the dataset's complexity and the interplay of various economic indicators, setting the stage for more in-depth visualization and analysis.

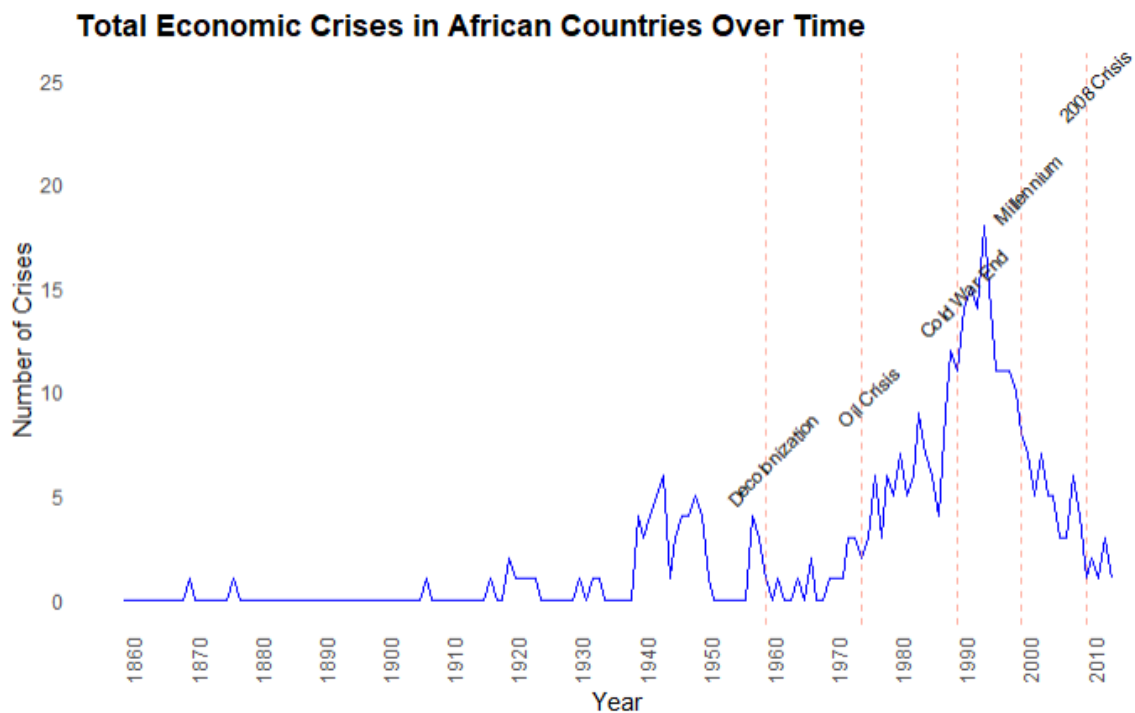
3. Visualization Creation

Research Question/Theme

Guiding our exploration is the question ***“How have economic crisis in African countries evolved, and what impacts have they had on key economic indicators, particularly exchange rates, in the context of historical events?”***

To address this question, four visualizations were created that spans across the frequency of economic crisis and its impact on the exchange rate of African countries. We would explore each of these visualizations in detail.

Visualization 1: Line Graph of Total Economic Crises Over Time

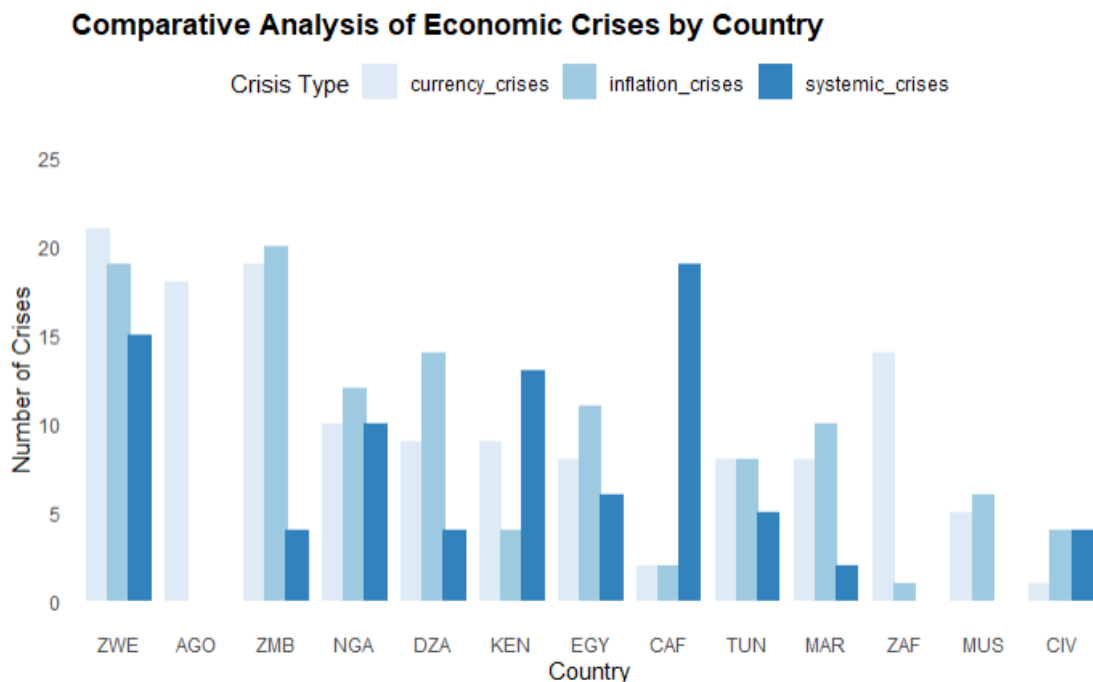


A line graph was chosen for its effectiveness in visualizing changes in a time series dataset, particularly in showcasing trends and identifying periods of economic crises (Cisneros, 2020). This choice aids in answering the research question by visually representing the frequency and timing of economic crises. The line chart reveals the fluctuating trend in economic crises in African countries over time, with significant spikes indicating intense crises, annotated to provide insights into potential causes.

Notable events, including decolonization in 1960, the 1975 global economic changes, the end of the Cold War in 1990, the turn of the millennium, and the aftermath of the 2008 financial crisis in 2010, are highlighted (Mkandawire, 1999).

The graph employs visualization techniques such as removing gridlines, using subtle colours, enhancing the title placement, and applying the gestalt principle of connection with faint dotted lines to emphasize significant spikes (Knafllic, 2015).

Visualization 2: Grouped Bar Chart for Comparative Analysis of Economic Crises by Country



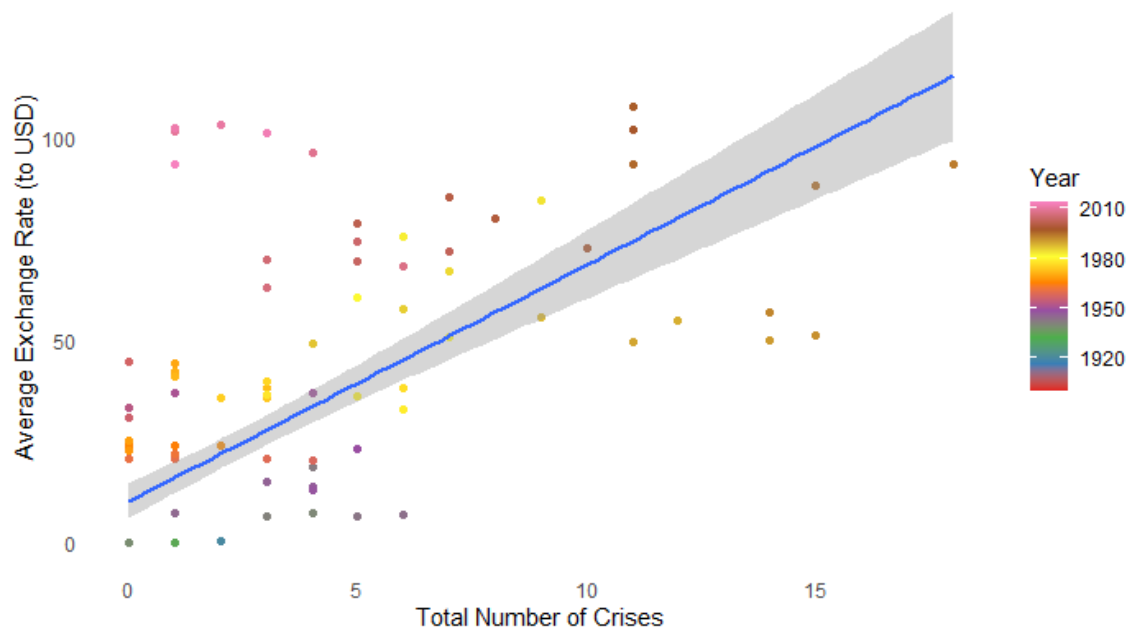
The grouped bar chart facilitates a comparative analysis of different types of economic crises (currency, inflation, and systemic) across diverse African countries. Chosen for its effectiveness in comparing multiple crisis categories across various nations, it aids in understanding the distribution and prevalence of these crises, aligning with the report's research question focus.

The chart displays bars for each country, representing the frequency of each crisis type, enabling a side-by-side comparison. This reveals patterns and identifies countries more susceptible to specific crises, complementing the line chart visualization. It goes beyond by illustrating how crises are distributed across countries, providing insights into anomalies and potential causal factors.

The creation of this graph adheres to visualization principles, eliminating borders and gridlines for enhanced focus on data Tufte (cited in Evergreen and Metzner, 2013). This simplicity aligns with Tufte's principle, reducing visual noise to allow the data to stand out.

Visualization 3: Scatter Plot of the Relationship between Economic Crisis and Exchange Rates

Economic Crises and Exchange Rates in African Countries

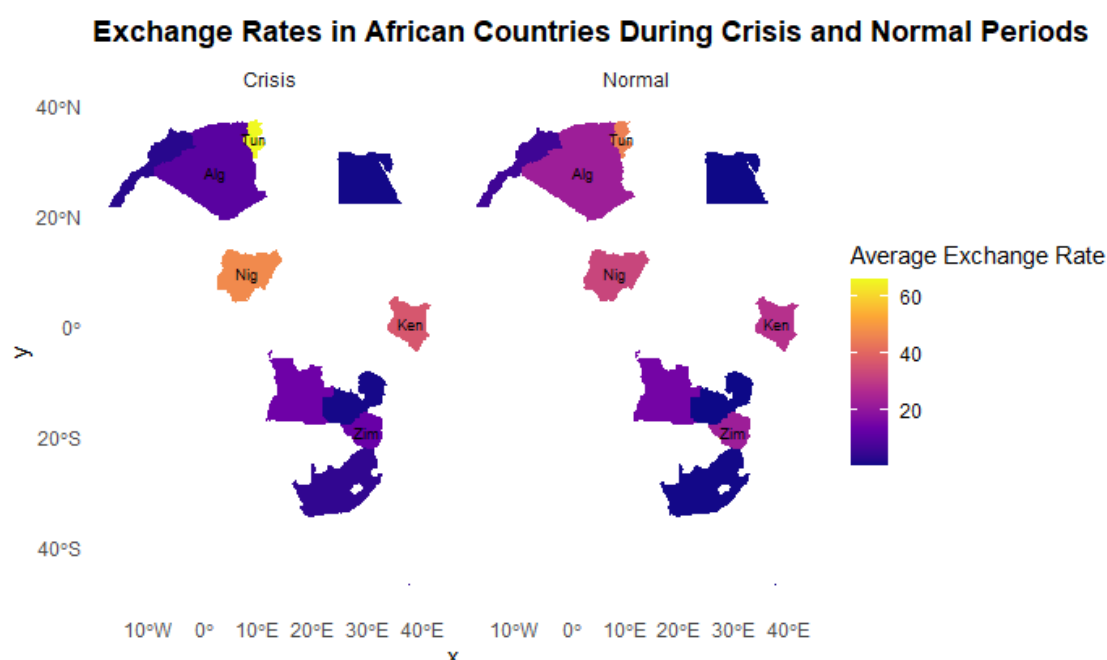


The scatter plot, acknowledged for its effectiveness in visualizing correlations (CFI Team, 2022), directly addresses the research question on the potential impact of economic crises on currency stability. Depicting each year based on the total number of economic crises (X-axis) and the average exchange rate to USD (Y-axis), the graph employs a trend line generated through linear regression. This trend line is pivotal, indicating a positive slope that implies, during years with more economic crises, African currencies tended to devalue against the USD, suggesting a correlation between crisis frequency and currency depreciation.

The scatter plot's choice proves adept for analyzing relationships between these variables, presenting patterns and trends visually. Complementing previous visualizations focused on exchange rates, it also provides a historical context by linking data points to specific events or periods of economic instability in Africa. Cross-referencing peak crisis years from a line chart with the scatter plot enhances our understanding of the crises-currency devaluation correlation.

The scatter plot, by linking data to historical events, offers a comprehensive historical context, revealing how external pressures and global economic downturns may have influenced exchange rates in African countries. Inclusion of outliers and using average exchange rates ensures a thorough analysis, capturing impacts from typical to extreme, aligning with the research question's emphasis on the evolution and impact of economic crises. Employing best practices for the visualization, the removal of gridlines and borders, along with the principle of similarity by grouping plots by years in colours, enhances clarity. The title's relocation to the top left improves readability, adhering to principles outlined by Knafllic (2015).

Visualization 4: Choropleth Map of Exchange Rates in African Countries during Crisis and Normal Periods



The use of choropleth maps in this analysis serves the purpose of illustrating spatial patterns and variations across Africa in response to economic crises, aligning with the research question on the potential impact of these crises on exchange rates. The maps, categorized into 'Crisis' and 'Normal' periods, employ colour intensity to represent the average exchange rate to the USD, with darker shades indicating weaker local currencies.

Annotations in specific countries like Algeria, Tunisia, Nigeria, Kenya, and Zimbabwe—provide a focused visual cue to nations undergoing significant exchange rate changes during crises, offering specificity to the analysis. Algeria's economic fluctuations tie to oil prices and political instability, Tunisia faces post-Arab Spring challenges impacting currency stability, Nigeria's oil-dependent economy correlates with historical exchange rate shifts, Kenya deals with diversified challenges like drought and political instability, and Zimbabwe's extreme outliers align with its hyperinflation crisis.

The choice of choropleth maps effectively adds a geographical dimension to the research, allowing examination of how different African countries respond to economic crises (Short, 2021). These maps complement previous visualizations by offering a unique spatial perspective, highlighting regional variations in exchange rate dynamics during economic turbulence and stability, a perspective not fully captured by earlier graphs focused on temporal or crisis-type comparisons.

4. Interpretation and Analysis

The visualizations reveal patterns, trends, and relationships in the evolution of economic crises in African countries and their impact on key economic indicators. The line graph identifies spikes correlated with major historical events, the grouped bar chart highlights country-specific crisis variations, and the scatter plot and choropleth map showcase the relationship between economic crises and exchange rates.

These insights include the evolution of crises over time, diverse impacts on different countries, and unexpected findings like extreme anomalies in Zimbabwe. Relating these findings to the research question, the visualizations collectively demonstrate the evolution of crises in alignment with historical events and underscore their impact on exchange rates during crisis periods.

The conclusions emphasize the varying economic vulnerability of African countries, influenced by factors such as economic diversification, political stability, and global economic trends. These insights emphasize the importance of robust economic policies to withstand external shocks and promote sustainable growth.

Key Takeaways

The analysis revealed significant findings, emphasizing the diverse economic resilience among African countries, with Nigeria, Kenya, Zimbabwe, and Algeria experiencing severe impacts from economic crises. The strong correlation between these crises and historical events highlighted the importance of contextual analysis, where political decisions, global economic trends, and regional conflicts played pivotal roles.

Policy implications and recommendations emerged, suggesting the necessity for tailored economic policies in African countries, focusing on economic diversification, robust financial regulation, and crisis preparedness to enhance stability and foster sustainable growth.

The discussion on outliers emphasized their importance in retaining a comprehensive dataset, providing crucial insights into the severity and nature of economic crises. The inclusion of outliers contributed to a more accurate depiction of the economic landscape and offered deeper insights into the challenges faced by different countries and the effectiveness of their responses.

5. Conclusion

The report analyses economic crises in African countries using scatter plots, grouped bar charts, and choropleth maps, while retaining outliers for a nuanced perspective. Highlighting historical nuances, the study reveals varying resilience across Africa. The scatter plot correlates total crises with currency devaluation, emphasizing historical contexts. Key findings include turbulent periods, anomalous years, and correlations strengthened by cross-referencing with line charts. The grouped bar chart and choropleth map contribute insights into country-specific crises and geographical patterns, enriching the understanding of economic challenges in Africa.

6. Appendix

Summary statistics for numerical values

```
summary(african_crises)
```

Checking for missing values

```
sum(is.na(african_crises))
```

```
## [1] 0
```

Correlation matrix for numerical variables

```
library(dplyr)
numerical_data <- african_crises %>% select_if(is.numeric)
cor_matrix <- cor(numerical_data, use = "complete.obs")
library(corrplot)
corrplot(cor_matrix, method = 'color', type = 'upper', order = 'hclust',
          tl.col = 'black', tl.srt = 45, addCoef.col = 'black', cl.lim = c(
-1, 1),
          tl.cex = 0.6, number.cex = 0.7)
par(mar = c(5, 4, 4, 2) + 0.1)
mtext("Correlation Matrix of African Economic Crisis Data", side = 3, line
= 3, cex = 1.2, adj = 0)
historical_events <- data.frame(
  year = c(1960, 1975, 1990, 2000, 2010),
  label = c('Event 1', 'Event 2', 'Event 3', 'Event 4', 'Event 5'),
  y_position = c(5, 10, 15, 20, 25)
)
p <- ggplot(african_crises_yearly, aes(x = year, y = total_crises)) +
  geom_line(color = 'blue') +
  labs(title = 'Total Economic Crises in African Countries Over Time',
       x = 'Year',
       y = 'Number of Crises') +
  theme_minimal() +
  theme(panel.grid.major = element_blank(), panel.grid.minor = element_bla
nk(), axis.text.x = element_text(angle = 90, hjust = 1)) +
  scale_x_continuous(breaks = seq(min(african_crises_yearly$year), max(afr
ican_crises_yearly$year), by = 10))

for(i in 1:nrow(historical_events)) {
  p <- p + geom_vline(xintercept = historical_events$year[i], linetype =
"dashed", color = "red") +
  annotate("text", x = historical_events$year[i], y = historical_eve
nts$y_position[i], label = historical_events$label[i], angle = 45, vjust =
1)
}
p
```

Boxplot for numerical variables to visualize outliers

```
par(mfrow = c(1, 4), mar = c(4, 4, 2, 1), oma = c(0, 0, 3, 0))
boxplot(african_crises$systemic_crisis, main="Systemic Crisis Outliers", c
ex.axis = 0.7, cex.main = 0.8)
boxplot(african_crises$exch_usd, main="Exchange Rate to USD Outliers", cex
.axis = 0.7, cex.main = 0.8)
boxplot(african_crises$gdp_weighted_default, main='GDP Weighted Default',
```

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```
cex.axis = 0.7, cex.main = 0.8)
boxplot(african_crises$inflation_annual_cpi, main="Annual CPI Inflation Rate Outliers", cex.axis = 0.7, cex.main = 0.8, ylim = c(0, 100))
mtext("Boxplot for Numerical Variables to Visualize Outliers", side = 3, outer = TRUE, line = 1, adj = 0, cex = 1.2, font = 2)
```

Line Chart of Economic Crisis Over Time

```
african_crises_yearly <- african_crises %>%
  group_by(year) %>%
  summarise(total_systemic_crisis = sum(systemic_crisis),
            total_currency_crises = sum(currency_crises),
            total_inflation_crises = sum(inflation_crises),
            total_crises = total_systemic_crisis + total_currency_crises +
total_inflation_crises)
historical_events <- data.frame(
  year = c(1960, 1975, 1990, 2000, 2010),
  label = c('Decolonization', 'Oil Crisis', 'Cold War End', 'Millennium'
, '2008 Crisis'),
  y_position = c(7, 10, 15, 20, 25)
)

p <- ggplot(african_crises_yearly, aes(x = year, y = total_crises)) +
  geom_line(color = 'blue') +
  labs(title = 'Total Economic Crises in African Countries Over Time',
       x = 'Year',
       y = 'Number of Crises') +
  theme_minimal() +
  theme(panel.grid.major = element_blank(), panel.grid.minor = element_bla
nk(), axis.text.x = element_text(angle = 90, hjust = 1), plot.title = elem
ent_text(face = "bold")) +
  scale_x_continuous(breaks = seq(min(african_crises_yearly$year), max(afr
ican_crises_yearly$year), by = 10))

for(i in 1:nrow(historical_events)) {
  p <- p + geom_vline(xintercept = historical_events$year[i], linetype =
"dashed", color = "#FF6347", alpha = 0.5) +
  annotate("text", x = historical_events$year[i], y = historical_eve
nts$y_position[i], label = historical_events$label[i], angle = 45, vjust =
1)
}

p
```

Comparative Analysis of Crises by Country

```
crisis_summary <- african_crises %>%
  group_by(cc3) %>%
  summarize(
    currency_crises = sum(currency_crises == 1, na.rm = TRUE),
    inflation_crises = sum(inflation_crises == 1, na.rm = TRUE),
    systemic_crises = sum(systemic_crisis == 1, na.rm = TRUE)
  ) %>%
  mutate(total_crises = currency_crises + inflation_crises + systemic_cris
es) %>%
  arrange(total_crises)
```

DATA VISUALIZATION ASSESSMENT 2

```
crisis_long <- pivot_longer(
  crisis_summary,
  cols = c(currency_crises, inflation_crises, systemic_crises),
  names_to = "crisis_type",
  values_to = "count"
)

ggplot(crisis_long, aes(x = reorder(cc3, -total_crises), y = count, fill =
crisis_type)) +
  geom_bar(stat = "identity", position = position_dodge(width = 0.8)) +
  scale_fill_brewer(palette = "Blues", name = "Crisis Type") +
  labs(title = "Comparative Analysis of Economic Crises by Country",
       x = "Country",
       y = "Number of Crises") +
  scale_y_continuous(breaks = seq(0, 25, by = 5), limits = c(0, 25)) +
  theme_minimal() +
  theme(
    legend.position = "top",
    panel.grid.major = element_blank(),
    panel.grid.minor = element_blank(),
    axis.text.x = element_text(angle = 0, hjust = 0.5),
    plot.title = element_text(face = "bold")
  )
```

Economic Crisis and Exchange Rates in African Countries

```
african_crises_yearly <- african_crises %>%
  group_by(year) %>%
  summarize(total_crises = sum(systemic_crisis + currency_crises + inflati
on_crises),
            avg_exchange_rate = mean(exch_usd, na.rm = TRUE))

scatter_plot <- ggplot(african_crises_yearly, aes(x = total_crises, y = av
g_exchange_rate, color = year)) +
  geom_point() +
  geom_smooth(method = 'lm') +
  labs(title = 'Economic Crises and Exchange Rates in African Countries',
       x = 'Total Number of Crises',
       y = 'Average Exchange Rate (to USD)',
       color = 'Year') +
  theme_minimal() +
  theme(panel.grid.major = element_blank(), panel.grid.minor = element_bla
nk(),
        plot.title = element_text(face = "bold"))

scatter_plot + scale_color_gradientn(colors = brewer.pal(8, "Set1"), limit
s = c(1900, 2014))
```

Exchange Rates in African Countries During Crisis and Normal Periods

```
library(dplyr)
library(ggplot2)
library(sf)
library(rnaturalearth)
```

DATA VISUALIZATION ASSESSMENT 2

```
library(rnaturalearthdata)
african_crises$crisis_period <- ifelse(african_crises$systemic_crisis == 1
| african_crises$currency_crises == 1 | african_crises$inflation_crises ==
1, 'Crisis', 'Normal')
exchange_rate_summary <- african_crises %>%
  group_by(country, crisis_period) %>%
  summarize(avg_exch_rate = mean(exch_usd, na.rm = TRUE), .groups = 'drop'
)

significant_countries <- exchange_rate_summary %>%
  group_by(country) %>%
  summarize(difference = max(avg_exch_rate) - min(avg_exch_rate), .groups
= 'drop') %>%
  arrange(desc(difference)) %>%
  filter(country %in% c("Nigeria", "Tunisia", "Algeria", "Zimbabwe", "Kenya"))

africa_map <- ne_countries(scale = "medium", continent = "africa", returnc
lass = "sf")
africa_exchange_map <- left_join(africa_map, exchange_rate_summary, by = c
("name" = "country")) %>%
  filter(!is.na(avg_exch_rate))

africa_exchange_map <- africa_exchange_map %>%
  st_transform(crs = st_crs(4326)) %>%
  mutate(geometry_centroid = st_centroid(geometry))

africa_exchange_map <- africa_exchange_map %>%
  mutate(x = st_coordinates(geometry_centroid)[,1],
         y = st_coordinates(geometry_centroid)[,2])

country_abbreviations <- data.frame(
  full_name = c("Nigeria", "Tunisia", "Algeria", "Zimbabwe", "Kenya"),
  abbreviation = c("Nig", "Tun", "Alg", "Zim", "Ken")
)

significant_countries <- significant_countries %>%
  left_join(country_abbreviations, by = c("country" = "full_name"))
significant_countries_with_coords <- significant_countries %>%
  left_join(africa_exchange_map %>% select(name, x, y), by = c("country" =
"name"))

ggplot(africa_exchange_map) +
  geom_sf(aes(fill = avg_exch_rate), color = NA) +
  geom_text(data = significant_countries_with_coords, aes(x = x, y = y, la
bel = abbreviation), check_overlap = TRUE, size = 2.5, hjust = 0.5, vjust
= 0.5) +
  facet_wrap(~crisis_period) +
  scale_fill_viridis_c(option = "C") +
  labs(title = 'Exchange Rates in African Countries During Crisis and Norm
al Periods', fill = 'Average Exchange Rate') +
  theme_minimal() +
```

DATA VISUALIZATION ASSESSMENT 2

```
theme(panel.grid.major = element_blank(), panel.grid.minor = element_blank(), plot.title = element_text(face = "bold"))
```


7. References

- CFI Team (2022). *Scatter Plot*. [online] Corporate Finance Institute. Available at: <https://corporatefinanceinstitute.com/resources/data-science/scatter-plot/>
- Chiri (2019). *Africa Economic, Banking and Systemic Crisis Data*. [online] www.kaggle.com. Available at: <https://www.kaggle.com/datasets/chirin/africa-economic-banking-and-systemic-crisis-data>
- Cisneros, M. (2020). *what is a line graph, how does a line graph work, and what is the best way to use a line graph?* [online] storytelling with data. Available at: <https://www.storytellingwithdata.com/blog/2020/3/24/what-is-a-line-graph>.
- Engineering Statistics Handbook (2019). *What are outliers in the data?* [online] Nist.gov. Available at: <https://www.itl.nist.gov/div898/handbook/prc/section1/prc16.htm>.
- Evergreen, S. and Metzner, C. (2013). Design Principles for Data Visualization in Evaluation. *New Directions for Evaluation*, 2013(140), pp.5–20. doi: <https://doi.org/10.1002/ev.20071>.
- Knafllic, C.N. (2015). *Storytelling with Data: a Data Visualization Guide for Business Professionals*. Hoboken, New Jersey: Wiley.
- Mkandawire, T. (1999). The Political Economy of Financial Reform in Africa. *Journal of International Development*, [online] pp.321–342. Available at: <https://onlinelibrary.wiley.com/doi/epdf/10.1002/%28SICI%291099-1328%28199905/06%2911%3A3%3C321%3A%3AAID-JID594%3E3.0.CO%3B2-V>
- Short, L. (2021). *What Is a Choropleth Map and Why Are They Useful?* [online] Population Education. Available at: <https://populationeducation.org/what-is-a-choropleth-map-and-why-are-they-useful/#:~:text=These%20maps%20allow%20us%20to>.
- Tufte, E.R. (1990). *Envisioning information*. Cheshire, Connecticut: Graphics Press.