UNIVERSITY OF WESTMINSTER

INFORMATICS INSTITUTE OF TECHNOLOGY

5DATA006C Data Visualisation and Communication

Portfolio

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01. Research Question and Data Sourcing

Research Question

"How do systemic factors and educational outcomes influence the underrepresentation of women in STEM (science, technology, engineering and mathematics) fields across Asia and Europe, even though there are growing efforts to close gender gaps?"

Data Sourcing

Various data sources were used to obtain the datasets related to the topic. The names of the datasets and their respective sources are mentioned below, along with the links for further reference.

Dataset	Source	Link
Female share of graduates from STEM programs %	World Bank Group	https://genderdata.worldbank.org/en/indicator/se-ter-grad-fe-zs?fieldOfStudy=Science%2C+Technology%2C+Engineering+and+Mathematics+%28STEM%29
Labour force participation rate of females above the age of 15	World Bank Group	https://genderdata.worldbank.org/en/indicator/sl-tlf-acti-zs
GERD as a percentage of GDP	UIS Statistics	https://data.uis.unesco.org/
Researchers (HC) - % Female	UIS Statistics	https://data.uis.unesco.org/
Literacy rate, youth female (% of females ages 15-24)	World Bank Group	https://data.worldbank.org/indicator/SE.ADT.1524.LT.FE.ZS
Literacy rate, adult total (% of people ages 15 and above)	World Bank Group	https://data.worldbank.org/indicator/SE.ADT.LITR.ZS
Gender Inequality Index	Our World in Data	https://ourworldindata.org/grapher/gender-inequality-index-from-the-human-development-report?tab=table

02. Data Preparation

Variables

The dataset contains the below mentioned variables.

- **GERD**: Gross domestic expenditure on research and development as a percentage of GDP, representing systemic investment in STEM.
- **Female_STEM_Graduates**: Female share of STEM graduates, showing the pipeline of women entering STEM fields.
- **GII**: Gender Inequality Index, measuring systemic gender disparities.
- **Female_Researchers**: Percentage of female researchers, representing workforce representation.
- **Female_Youth_Literacy** and **Adult_Literacy**: Literacy rates, indicating foundational education levels.
- **Female_Labour_Force:** Female (ages 15+) share of Labour force participation rate.

Data Preparation Steps

Excel was used for data preparation.

1. Data Cleaning

- Column names were standardised to ensure that they remain consistent. For example, column names such as 'Economy' and 'Location' were renamed 'Country', and 'Time' was renamed 'Year'. Metric names, such as Indicator Name for STEM Graduates, were renamed to Female_STEM_Graduates for clarity and usability. This step makes the merging process and the analysis easier.

e.g.: The first few rows of the original 'STEM_Graduates' dataset prior to standardising.

Share of graduates by field, female (%)

Economy	Year	Economy Code	Female share of graduates from Science, Technology, Engineering and Mathematics (STEM) programmes, tertiary (%)
Afghanistan	2019	AFG	
Albania	2018	ALB	46.653
Algeria	2018	DZA	58.170
American Samoa	2019	ASM	
Andorra	2018	AND	0.000
Angola	2015	AGO	38.416
Antigua and Barbuda	2019	ATG	
Argentina	2019	ARG	
Armenia	2018	ARM	39.811
Aruba	2016	ABW	40.000
Australia	2017	AUS	32.076
Austria	2016	AUT	25.903
Azerbaijan	2018	AZE	35.099
Bahamas, The	2019	BHS	
Bahrain	2018	BHR	41.213
Bangladesh	2018	BGD	20.553
Barbados	2019	BRB	
Belarus	2018	BLR	27.416

The first few rows of the 'Female_STEM_Graduates' dataset after standardising

Country	Year	Economy Code	Female_STEM_Graduates
Afghanistan	2019	AFG	
Albania	2018	ALB	46.653
Algeria	2018	DZA	58.17
American Sa	2019	ASM	
Andorra	2018	AND	0
Angola	2015	AGO	38.416
Antigua and	2019	ATG	
Argentina	2019	ARG	
Armenia	2018	ARM	39.811
Aruba	2016	ABW	40
Australia	2017	AUS	32.076
Austria	2016	AUT	25.903
Azerbaijan	2018	AZE	35.099
Bahamas, Th	2019	BHS	
Bahrain	2018	BHR	41.213
Bangladesh	2018	BGD	20.553
Barbados	2019	BRB	
Belarus	2018	BLR	27.416

- Unnecessary columns such as ‘country code’, ‘indicator name’, and ‘indicator code’ were removed to simplify the dataset.

e.g.: The first few rows of the original ‘Female_Researchers’ dataset prior to removing unnecessary columns.

SCNOPRI_IND	Indicators	LOCATION	Country	TIME	Value	Flag Codes	Flags
FRESP_THC	Researchers (HC) - % Female	AUT	Austria	2019	30.39204		
FRESP_THC	Researchers (HC) - % Female	AUT	Austria	2021	31.25169		
FRESP_THC	Researchers (HC) - % Female	BEL	Belgium	2019	32.62094		
FRESP_THC	Researchers (HC) - % Female	BEL	Belgium	2021	33.52072		
FRESP_THC	Researchers (HC) - % Female	CZE	Czechia	2018	26.56457		
FRESP_THC	Researchers (HC) - % Female	CZE	Czechia	2019	27.18323		
FRESP_THC	Researchers (HC) - % Female	CZE	Czechia	2020	27.59806		
FRESP_THC	Researchers (HC) - % Female	CZE	Czechia	2021	27.10107		
FRESP_THC	Researchers (HC) - % Female	CZE	Czechia	2022	27.68677		
FRESP_THC	Researchers (HC) - % Female	DNK	Denmark	2019	35.31743		
FRESP_THC	Researchers (HC) - % Female	FIN	Finland	2018	33.70387		
FRESP_THC	Researchers (HC) - % Female	FIN	Finland	2019	33.74449		
FRESP_THC	Researchers (HC) - % Female	FIN	Finland	2020	33.40077		
FRESP_THC	Researchers (HC) - % Female	FIN	Finland	2021	32.80407		
FRESP_THC	Researchers (HC) - % Female	FIN	Finland	2022	33.58727	‡	UIS Estimation
FRESP_THC	Researchers (HC) - % Female	FRA	France	2020	29.4111		
FRESP_THC	Researchers (HC) - % Female	FRA	France	2021	29.87066		

The first few rows of the ‘Female_Researchers’ dataset after standardising and removing unnecessary columns.

Country	Year	Female_Researchers	
Austria	2019	30.39204	
Austria	2021	31.25169	
Belgium	2019	32.62094	
Belgium	2021	33.52072	
Czechia	2018	26.56457	
Czechia	2019	27.18323	
Czechia	2020	27.59806	
Czechia	2021	27.10107	
Czechia	2022	27.68677	
Denmark	2019	35.31743	
Finland	2018	33.70387	
Finland	2019	33.74449	
Finland	2020	33.40077	
Finland	2021	32.80407	
Finland	2022	33.58727	
France	2020	29.4111	
France	2021	29.87066	
France	2022	29.72227	
Germany	2019	28.05404	
Germany	2021	29.35781	

- The columns of the original ‘Female_Youth_Literacy’ and ‘Adult_Literacy’ were manually organised into a new table with these three columns: Country, Column, Value (Female_Youth_Literacy’ and ‘Adult_Literacy’). It was done to ensure consistency. Only Asian and European countries were organised into the country column to make cleaning easier.

e.g.: The first few rows of the original ‘Female_Youth_Literacy’ dataset prior to organising.

Country	2017	2018	2019	2020	2021	2022	2023
Aruba				99.41000366			
Africa Eastern and Southern	80.2280426	80.83635712	81.56388092	81.83467102	82.23442841	82.64910126	82.98766327
Afghanistan					42	44.17171097	
Africa Western and Central	62.3158989	65.03798676	64.84825897	64.93427277	65.29728699	65.64781189	65.89544678
Angola						80.69999695	
Albania	99.52555847					99.90000153	
Andorra							
Arab World	81.99842834	82.46421814	82.88758087	83.3006897	83.73696136	84.07437897	84.35565948
United Arab Emirates			99		100	100	
Argentina							
Armenia	100			100			
American Samoa							
Antigua and Barbuda							
Australia							
Austria							
Azerbaijan	100		100				100
Burundi	86					93.16000366	
Belgium							
Benin	50.98535919				59.18643951	59.09999847	
Burkina Faso		54	44		58.75799942	51.68000031	
Bangladesh	94	95	96	96	96		
Bulgaria					97.83000183		
Bahrain						99	99
Bahamas, The							
Bosnia and Herzegovina						99.69999695	
Belarus			100				

The first few rows of the ‘Female_Youth_Literacy’ dataset after organising.

Country	Year	Female_Youth_Literacy
Afghanistan	2021	42
Afghanistan	2022	44.17171097
Albania	2017	99.52555847
Albania	2022	99.90000153
Armenia	2017	100
Armenia	2020	100
Azerbaijan	2017	100
Azerbaijan	2019	100
Azerbaijan	2023	100
Bangladesh	2017	94
Bangladesh	2018	95
Bangladesh	2019	96
Bangladesh	2020	96
Bangladesh	2021	96
Bulgaria	2021	97.83000183
Bahrain	2022	99
Bahrain	2023	99
Bosnia and Herzegovina	2022	99.69999695
Belarus	2019	100
Brunei Darussalam	2021	99.83000183
Bhutan	2017	93
Bhutan	2022	98
China	2020	100
Cyprus	2021	99.91000366
East Asia & Pacific	2017	98.62120056

- A new column named ‘Region’ was added to narrow the data to only Asia and Europe. It also filters out rows belonging to other regions.

The following code was used on Excel to assign regions based on the country name. (support.microsoft.com, n.d.)

```
=IF(OR(A2="India", A2="China", A2="Japan", A2="South Korea", A2="Indonesia", A2="Pakistan", A2="Bangladesh", A2="Russia", A2="Vietnam",
A2="Turkey", A2="Iran", A2="Thailand", A2="Myanmar", A2="Afghanistan", A2="Saudi Arabia", A2="Uzbekistan", A2="Malaysia", A2="Yemen",
A2="Nepal", A2="North Korea", A2="Sri Lanka", A2="Kazakhstan", A2="Syria", A2="Cambodia", A2="Jordan", A2="Azerbaijan", A2="United Arab
Emirates", A2="Tajikistan", A2="Israel", A2="Laos", A2="Lebanon", A2="Kyrgyzstan", A2="Turkmenistan", A2="Singapore", A2="Oman", A2="State
of Palestine", A2="Kuwait", A2="Georgia", A2="Mongolia", A2="Armenia", A2="Qatar", A2="Bahrain", A2="Timor-Leste", A2="Maldives",
A2="Bhutan"),
"Asia",
IF(OR(A2="Germany", A2="France", A2="United Kingdom", A2="Italy", A2="Spain", A2="Ukraine", A2="Poland", A2="Romania", A2="Netherlands",
A2="Belgium", A2="Greece", A2="Czech Republic", A2="Portugal", A2="Sweden", A2="Hungary", A2="Belarus", A2="Austria", A2="Switzerland",
A2="Bulgaria", A2="Serbia", A2="Denmark", A2="Finland", A2="Slovakia", A2="Norway", A2="Ireland", A2="Croatia", A2="Moldova",
A2="Slovenia", A2="North Macedonia", A2="Albania", A2="Kosovo", A2="Montenegro", A2="Luxembourg", A2="Malta"),
"Europe",
"Other"))
```

- A filter was added to the ‘Region’ column to exclude rows where Region equals "Other".

e.g.: The first few rows of the ‘GERD’ dataset after the step above.

Country	Year	Female_Labour_Force	Region
Afghanistan	2023	4.828	Asia
Afghanistan	2022	5.153	Asia
Afghanistan	2021	14.787	Asia
Afghanistan	2020	16.463	Asia
Afghanistan	2019	18.402	Asia
Afghanistan	2018	19.836	Asia
Afghanistan	2017	21.227	Asia
Afghanistan	2016	20.141	Asia
Afghanistan	2015	19.096	Asia
Albania	2023	52.824	Europe
Albania	2022	52.919	Europe
Albania	2021	51.788	Europe
Albania	2020	50.089	Europe
Albania	2019	52.815	Europe
Albania	2018	51.284	Europe
Albania	2017	49.609	Europe
Albania	2016	49.763	Europe
Albania	2015	46.989	Europe
Armenia	2023	56.001	Asia
Armenia	2022	56.491	Asia
Armenia	2021	58.156	Asia

- Important data such as the percentage of female STEM graduates, Adult Literacy and Female youth literacy were missing for countries such as Israel, Japan, Netherlands, Norway, Slovenia, etc. Those countries were removed from each dataset using the formatting option on Excel to ensure consistency and data integrity and to make the merging process easier. Also, countries such as Kosovo, Tajikistan, Timor-Leste, and Montenegro were removed since they lacked multiple data records and had a low impact on the topic.

- The missing data values of impactful countries such as Kuwait, Lebanon, Pakistan, and Switzerland, etc. in the 'Female_STEM_Graduates', 'Female_Youth_Literacy' and 'Adult_Literacy' datasets were calculated using the average of two countries that belong to the same sub-continent.

- Multiple duplicate data records were found in the 'Female_Researchers' dataset. They were removed for clarity.

- The common years in all datasets which are 2017, 2018, 2019 and 2020 were retained prior to merging using R Studio.

- The Excel sheets were saved as separate CSV files, and they were merged into one dataset called 'Merged_Dataset.csv' on the common keys: 'Country' and 'Year' using R Studio. The missing data in the merged dataset was replaced as '0'.

```r
# The folder path
setwd("/Users/sandasmiwijesuriya/Desktop/DV PORTFOLIO")

# Read the datasets
fem_stem_graduates <- read.csv("Female_STEM_Graduates.csv")
gerd <- read.csv("GERD.csv")
adult_literacy <- read.csv("Adult_Literacy.csv")
fem_youth_literacy <- read.csv("Female_Youth_Literacy.csv")
gii <- read.csv("GII.csv")
fem_labour_force <- read.csv("Female_Labour_Force.csv")
fem_researchers <- read.csv("Female_Researchers.csv")

# Merging datasets on the keys : Country and Year
merged_data <- merge(fem_stem_graduates, gerd, by = c("Country", "Year"), all = TRUE)

merged_data <- merge(merged_data, adult_literacy, by = c("Country", "Year"), all = TRUE)

merged_data <- merge(merged_data, fem_youth_literacy, by = c("Country", "Year"), all = TRUE)

merged_data <- merge(merged_data, gii, by = c("Country", "Year"), all = TRUE)

merged_data <- merge(merged_data, fem_labour_force, by = c("Country", "Year"), all = TRUE)

merged_data <- merge(merged_data, fem_researchers, by = c("Country", "Year"), all = TRUE)

# Handle missing values
merged_data[is.na(merged_data)] <- 0

# Save the Merged Dataset
write.csv(merged_data, "Merged_Dataset.csv", row.names = FALSE)
```

- The First Few Rows of the Merged Dataset called 'Merged_Dataset.csv'.

Merged_Dataset

Country	Year	Female_STEM_Graduates	GERD	Adult_Literacy	Female_Youth_Literacy	GII	Female_Labour_Force	Female_Researchers
Albania	2017	0	0	98.81623077	99.52555847	0	49.609	0
Albania	2018	46.653	0	0	0	0	51.284	0
Albania	2019	0	0	0	0	0.131	52.815	0
Albania	2020	0	0	0	0	0.129	50.089	0
Armenia	2017	0	0.22788	100	100	0	55.772	0
Armenia	2018	39.811	0.18876	0	0	0	55.765	50.38416
Armenia	2019	0	0.17854	0	0	0.219	57.625	51.51695
Armenia	2020	0	0.2092	100	100	0.223	57.689	53.32569
Armenia	2021	0	0	0	0	0	0	53.05958
Armenia	2022	0	0	0	0	0	0	52.88971
Azerbaijan	2017	0	0.18468	100	100	0	62.419	0
Azerbaijan	2018	35.099	0.18416	0	0	0	62.988	58.56925
Azerbaijan	2019	0	0.20013	100	100	0.317	65.714	54.96094
Azerbaijan	2020	0	0.2239	0	0	0.333	64.728	54.54469
Azerbaijan	2021	0	0	0	0	0	0	55.4477
Azerbaijan	2022	0	0	0	0	0	0	57.92432
Bahrain	2017	0	0	0	0	0	43.54	0
Bahrain	2018	41.213	0	0	0	0	44.067	0
Bahrain	2019	0	0	0	0	0.194	44.354	0
Bahrain	2020	0	0	0	0	0.197	43.484	0
Bangladesh	2017	0	0	73	94	0	36.449	0
Bangladesh	2018	20.553	0	74	95	0	36.703	0

03. Exploratory Data Analysis

Univariate Analysis

Summary Statistics

```
# Summary Statistics
summary(merged_data)
```

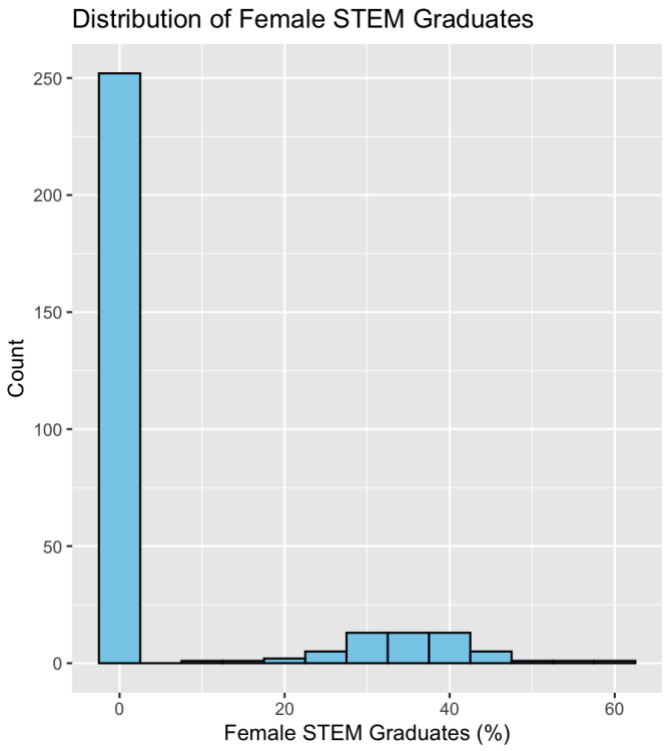
```
   Country               Year      Female_STEM_Graduates      GERD        Adult_Literacy   Female_Youth_Literacy
Length:308         Min.   :2015   Min.   : 0.000        Min.   :0.0000   Min.   :  0.00   Min.   :  0.00
Class :character   1st Qu.:2018   1st Qu.: 0.000        1st Qu.:0.0000   1st Qu.:  0.00   1st Qu.:  0.00
Mode  :character   Median :2019   Median : 0.000        Median :0.1298   Median :  0.00   Median :  0.00
                   Mean   :2019   Mean   : 6.336        Mean   :0.6421   Mean   : 18.96   Mean   : 19.84
                   3rd Qu.:2020   3rd Qu.: 0.000        3rd Qu.:1.1211   3rd Qu.:  0.00   3rd Qu.:  0.00
                   Max.   :2022   Max.   :60.764        Max.   :3.4896   Max.   :100.00   Max.   :100.00
      GII          Female_Labour_Force Female_Researchers
Min.   :0.00000   Min.   : 0.00       Min.   : 0.00
1st Qu.:0.00000   1st Qu.: 0.00       1st Qu.: 0.00
Median :0.00000   Median :44.50       Median :31.82
Mean   :0.08108   Mean   :33.63       Mean   :25.34
3rd Qu.:0.10700   3rd Qu.:55.01       3rd Qu.:44.35
Max.   :0.78900   Max.   :69.72       Max.   :76.84
```

The summary statistics provide valuable insights into gender representation in education. The analysis reveals disparities that reveal areas which need attention from policymakers and stakeholders to promote gender equality in STEM fields.

Visualisations of Individual Variables

1. Distribution of Female STEM Graduates

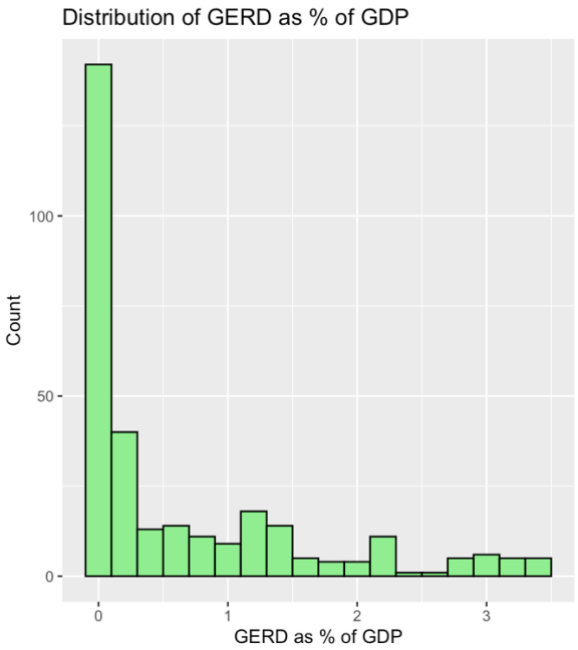
```
# 1.Distribution of Female STEM Graduates
ggplot(merged_data, aes(x = Female_STEM_Graduates)) +
  geom_histogram(binwidth = 5, fill = "skyblue", color = "black") +
  labs(x = 'Female STEM Graduates (%)',  y = 'Count',
    title = 'Distribution of Female STEM Graduates')
```



The histogram above shows that the distribution of female STEM graduates is skewed to the lower percentages. This indicates the underrepresentation of women in STEM in the world.

2. Distribution of GERD

```
# 2.Distribution of GERD
ggplot(merged_data, aes(x = GERD)) +
  geom_histogram(binwidth = 0.2, fill = "lightgreen", color = "black") +
  labs(x = 'GERD as % of GDP', y = 'Count',
    title = 'Distribution of GERD as % of GDP')
```

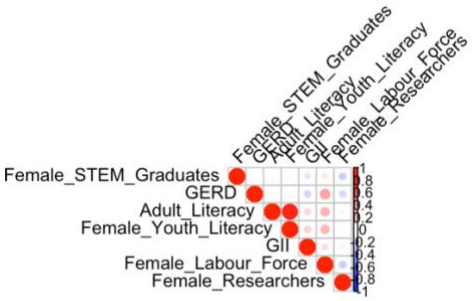


The histogram above shows how GERD as a percentage of GDP is distributed across countries.

Multivariate Analysis

Correlation Analysis

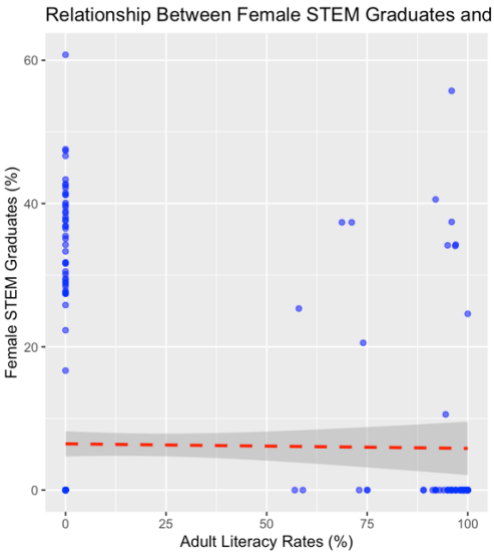
```
# Calculate the correlation matrix
correlation_matrix <- cor(clean_data, use = "complete.obs")

# Plot the correlation matrix
corrplot(correlation_matrix, method = "circle", type = "upper",
         tl.col = "black", tl.srt = 45, col = colorRampPalette(c("blue", "white", "red"))(200))
```



The correlation matrix heatmap indicates relationships between various variables such as female STEM graduates, GERD (Gross Expenditure on Research and Development), adult literacy rates, and GII. (Wagavkar, 2023)

Scatter Plot for Female STEM Graduates VS Adult Literacy Rates

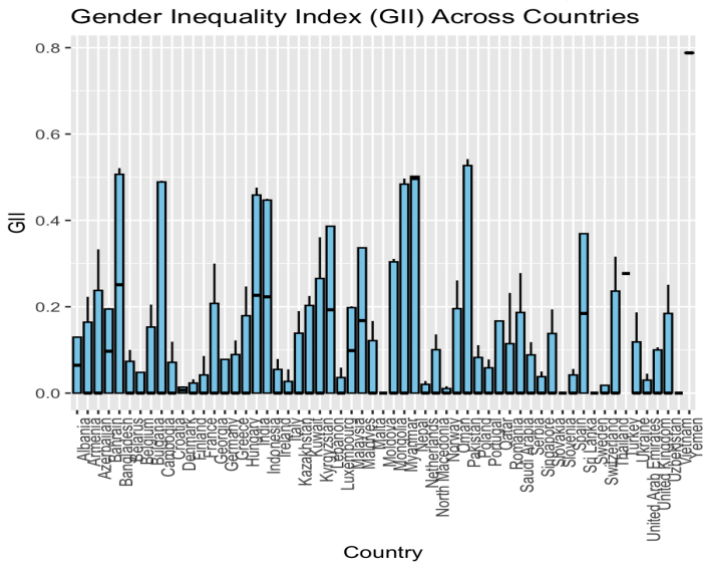
```r
# Scatter Plot: Female STEM Graduates vs. Adult Literacy Rates

ggplot(merged_data, aes(x = Adult_Literacy, y = Female_STEM_Graduates)) +
  geom_point(color = "blue", alpha = 0.6) +
  geom_smooth(method = "lm", color = "red", linetype = "dashed") +
  labs( x = "Adult Literacy Rates (%)", y = "Female STEM Graduates (%)",
    title = "Relationship Between Female STEM Graduates and Adult Literacy Rates")
```



The scatter plot shows a positive trend between female STEM graduates and adult literacy rates, reinforcing the idea that higher literacy rates contribute to greater female participation in STEM. Outliers may indicate specific countries with unique educational policies or cultural factors that affect women's education.

Box Plot for GII Across Different Countries

```r
# Box Plot: GII Across Different Countries
ggplot(merged_data, aes(x = Country, y = GII)) +
  geom_boxplot(fill = "skyblue", color = "black", outlier.color = "red", outlier.shape = 16) +
  labs(x = "Country", y = "GII",
    title = "Gender Inequality Index (GII) Across Countries",
  ) +
  theme(axis.text.x = element_text(angle = 90, hjust = 1))
```

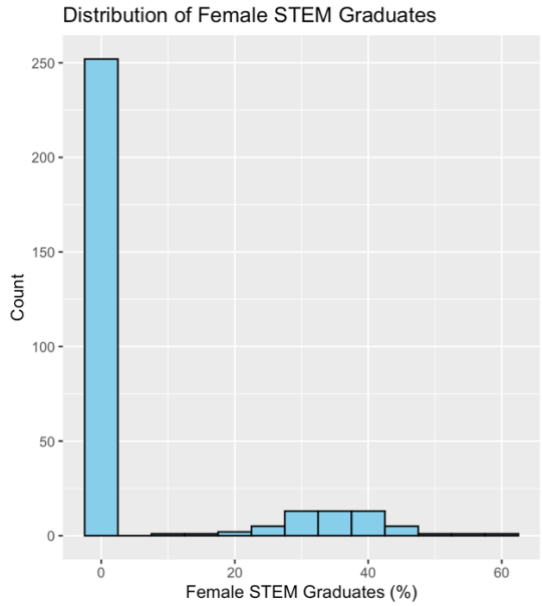


The box plot shows countries with lower GII values cluster together, indicating better gender equality. There are still significant outliers exist, which show that some countries experience gender inequality compared to others.

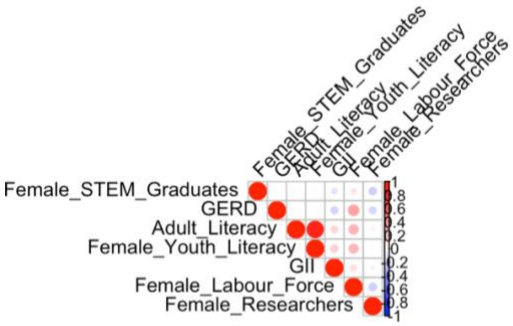
04. Data Storytelling

Women remain significantly underrepresented in STEM (Science, Technology, Engineering, and Mathematics) fields, despite growing efforts to reduce gender inequalities.
Getting more women into STEM education will positively impact economic growth in Europe and Asia. However, despite good employment opportunities and highly productive jobs in this area, a low proportion of women are currently studying and graduating in STEM subjects. (European Institute for Gender Equality, 2017). The purpose of this analysis is to understand the barriers women face better and identify actionable strategies to promote gender equality. Understanding these disparities is an academic exercise and a societal necessity to foster inclusive innovation and economic development.

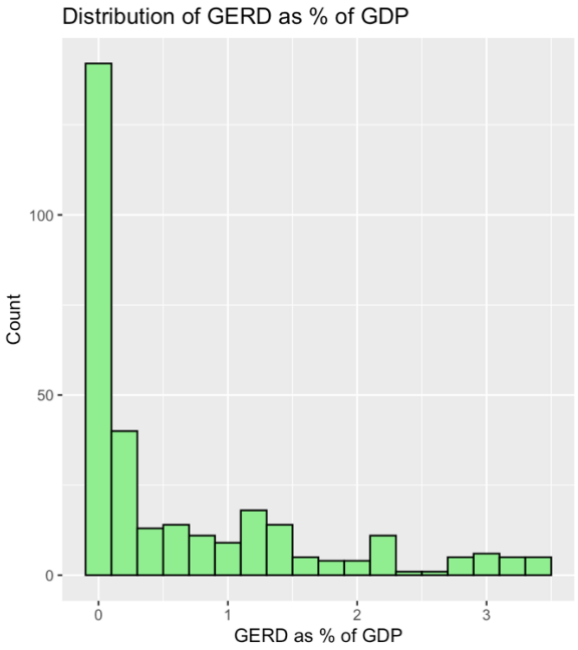
The visualization below reveals significant disparities in female representation in STEM fields. As shown in the histogram of Female STEM Graduates, most countries have a disproportionately low percentage of women graduating in STEM. This underrepresentation reflects wider scope of systemic challenges, including cultural norms, educational policies, and access to other resources.



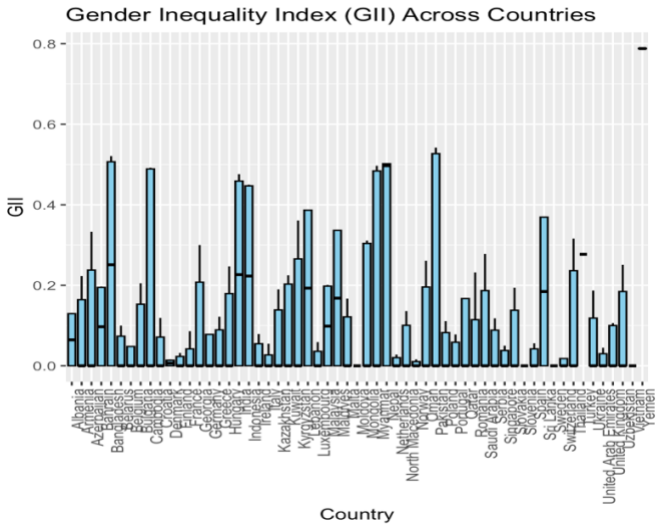
A strong positive correlation between adult literacy rates and the percentage of female STEM graduates suggests that improving literacy is a mandatory step towards overcoming gender disparities in STEM. Countries with higher literacy rates generally perceive more women pursuing STEM education. This highlights the importance of empowering women to break into male dominated fields. For example, European countries with strong literacy programs tend to show better representation of women in STEM compared to the countries with weaker education infrastructure. (European Institute for Gender Equality, 2017)



GERD (Gross Expenditure on Research and Development) shapes the innovation capacity of a country, even though, the data indicates that higher GERD percentages aren't solely responsible to ensure gender parity in STEM. While European nations with high GERD values often lead to female STEM participation, cultural and institutional factors also significantly influence these outcomes. This highlights the need for policies integrating gender inclusivity with economic and technological investment. (UNDP, 2024)



The box plot of the Gender Inequality Index (GII) across countries reveals clusters of nations with lower GII scores, showing better gender equality. However, the outliers highlight regions where women face systemic disadvantages in education, employment, and social rights.



Especially, in some Asian countries, traditional gender roles and limited access to higher education act as barriers, even in nations with robust economic development. On the other hand, European countries like Denmark and Finland, with proactive gender equality policies, demonstrate comparatively lower GII scores and better outcomes in female participation in STEM and research. (UNESCO, 2017)

The analysis above reveals the roles of education, economic investment, and cultural factors in shaping gender equality in STEM.

05. References

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