Software Code and Solution Report

Constructing a Python software artefact for data analysis

Word Count: 1497

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Abstract

This report investigates the interplay between various geodemographic, economic, and educational indicators across countries, using data from 2023. By analyzing correlations between key variables, the study aims to uncover underlying factors influencing national development. The findings reveal significant insights, including the impact of population size on economic output, the environmental costs of economic growth, and the role of education in improving health outcomes. These insights inform targeted recommendations for policymakers to foster sustainable development and enhance global well-being.

Data Collection

Data Sources and Volume Collected

For this report, three datasets from 2023 were utilized to understand the drivers of national development and the interdependencies between geodemographic, economic, and educational indicators across various countries. These indicators serve as empirical evidence for exploring the interactions among these dimensions, providing valuable insights for both national and international policymaking.

Each dataset was sourced from established, open-source platforms (Kaggle and Data World). The geodemographic and economic data files each contain 234 and 195 rows of data, while the educational data file includes data for 202 countries, totalling 631 rows when combined. These datasets were downloaded in CSV format to facilitate easy integration and analysis using Python's pandas library on Google Colab.

Data Cleaning Processes

Data cleaning was performed to ensure the accuracy, consistency, and usability of the datasets. Initially, a 'ISO-8859-1' encoding was applied, specified to handle any non-ASCII characters to avoid errors during the merging process. Any newline characters and excess whitespace were also removed.

The column names relevant to country identifiers in each dataset were standardized to 'Country'. This standardization allowed for smoother data analysis when referring to multiple dimensions, using 'Country' as a reference point.

Furthermore, a dictionary for country name corrections was applied across the datasets to standardize variations in country naming conventions (e.g., converting "USA" to "United States").

The data frames were merged based on the 'Country' Column using an inner join operation, which ensures that only records corresponding to countries present in all datasets were retained. This reduced the total number of records for comparison, however, ensured consistency and complete data across all dimensions. The result was a merged data frame containing 186 records and 74 indicators (dimensions).

The 'clean_and_convert' function refines the dataset by removing extra characters (e.g., '$', ',', '%'). It then converts applicable columns into numeric format, enabling quantitative analysis. Additionally, the 'process_dataframe' function cleans each column except the 'Country' variable, preserving the categorical integrity by excluding it from numerical conversions. Hence, any missing values across numeric columns were addressed using a median imputation strategy.

Finally, the 'drop()' function was also utilized to effectively remove duplicate and redundant columns that didn't support the analysis. Each step was methodically verified by printing out the dataset's structure post-cleanup to confirm the effectiveness of the cleaning processes. By the end of the cleaning process, 20 key dimensions (excluding the 'Country' column) were selected to serve as the foundation for the data analysis.

Data Analysis

The dimensions extracted from the data collection will be used to establish relevant assumptions based on correlations and statistical analyses. Graphs and charts will visually underscore each correlation highlighting key indicators across geographical, social, economic, and educational spheres. By identifying these areas, the analysis aims to reveal deeper insights into the causes and implications of observed patterns, supporting well-grounded recommendations and conclusions for policymakers.

Correlation Analysis

A correlation matrix was formulated to identify the most relevant and significant relationships between variables. These key correlations will be utilized to create visual aids, allowing for a more focused exploration of data patterns and trends. However, it is

important to note that correlation does not imply causation. Hence, any recommendations and assumptions will be considered with caution and substantiated through additional research.

Figure I: Heatmap of Correlation Matrix (Pearson Correlation)

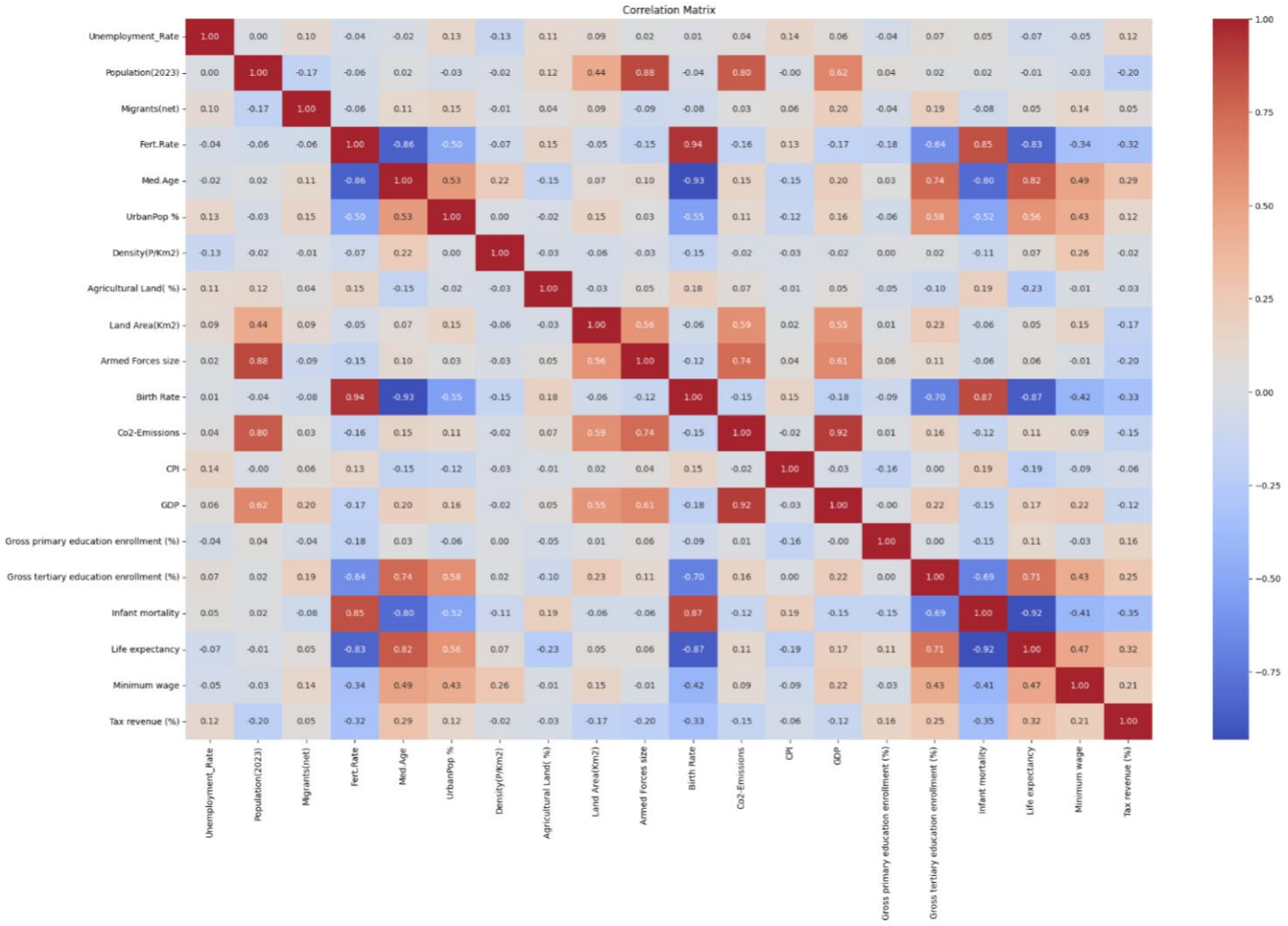


Figure II: Refined Correlation Matrix

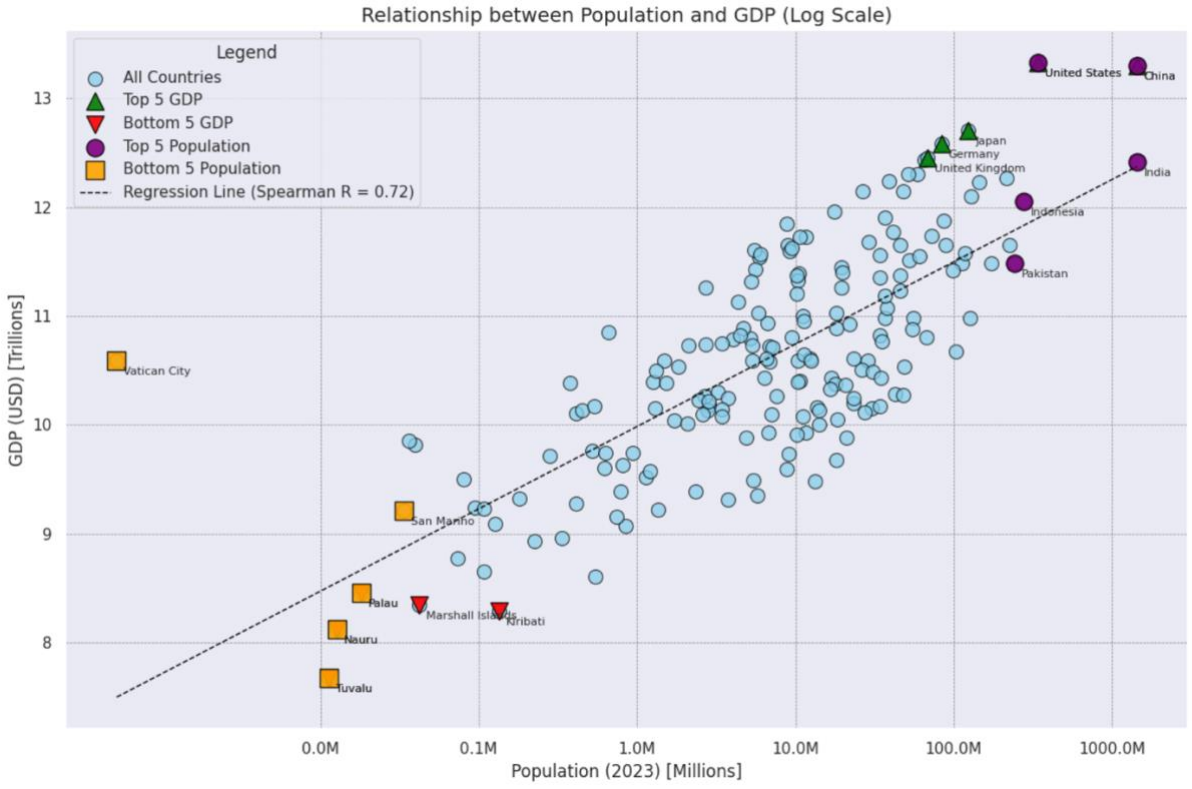
Figure II represents a refined correlation matrix highlighting key variable relationships that will be the focal point for further graphical analysis.

	GDP	Co2-Emissions	Armed Forces Size	Life Expectancy	Infant Mortality	Birth rate	Gross Tertiary enrollement %	Urban Population %	Minimum Wage	Tax Revenue %
Population	0.62	0.8	0.88							
Fert.Rate				-0.83	0.85	0.94				
Median Age				0.82	-0.8	-0.93	0.74	0.53		
Urban Pop %				0.56	-0.52	-0.55	0.58		0.43	
Birth Rate				-0.87	0.87		-0.7			
Co2-Emissions	0.92									
Tertiary Enrollement				0.71	-0.69				0.43	
Infant mortality				-0.92					-0.41	-0.35
Life expectancy									0.47	0.32

Graphical Representations

Logarithmic scales were utilized in the graphs to visualize data with wide-ranging values (Robbins, 2012). Additionally, scatter plots will used exclusively because they effectively illustrate the correlation and interdependencies between two variables.

Graph I: Population & GDP



There is a moderately strong positive correlation that exists between population and GDP (Spearman R = 0.72), indicating that countries with larger populations generally have higher GDPs. This suggests that population size can be a significant factor in a country's economic output.

The U.S. and China significantly outperform other countries with similar populations in terms of GDP, highlighting the influence of other factors like economic policies and technological advancements. Conversely, some smaller nations like the Vatican City exhibit high GDPs per capita, suggesting that population size is not the sole determinant of economic performance.

Table I: Top and Bottom Nations by GDP and Population

Top 5 GDP

	Country	GDP
177	United States	21427700000000.0
34	China	19910000000000.0
80	Japan	5081769542380.0
61	Germany	3845630030824.0
175	United Kingdom	2827113184696.0

Bottom 5 GDP

	Country	GDP
125	Palau	283994900.0
102	Marshall Islands	221278000.0
84	Kiribati	194647202.0
114	Nauru	133000000.0
171	Tuvalu	47271463.0

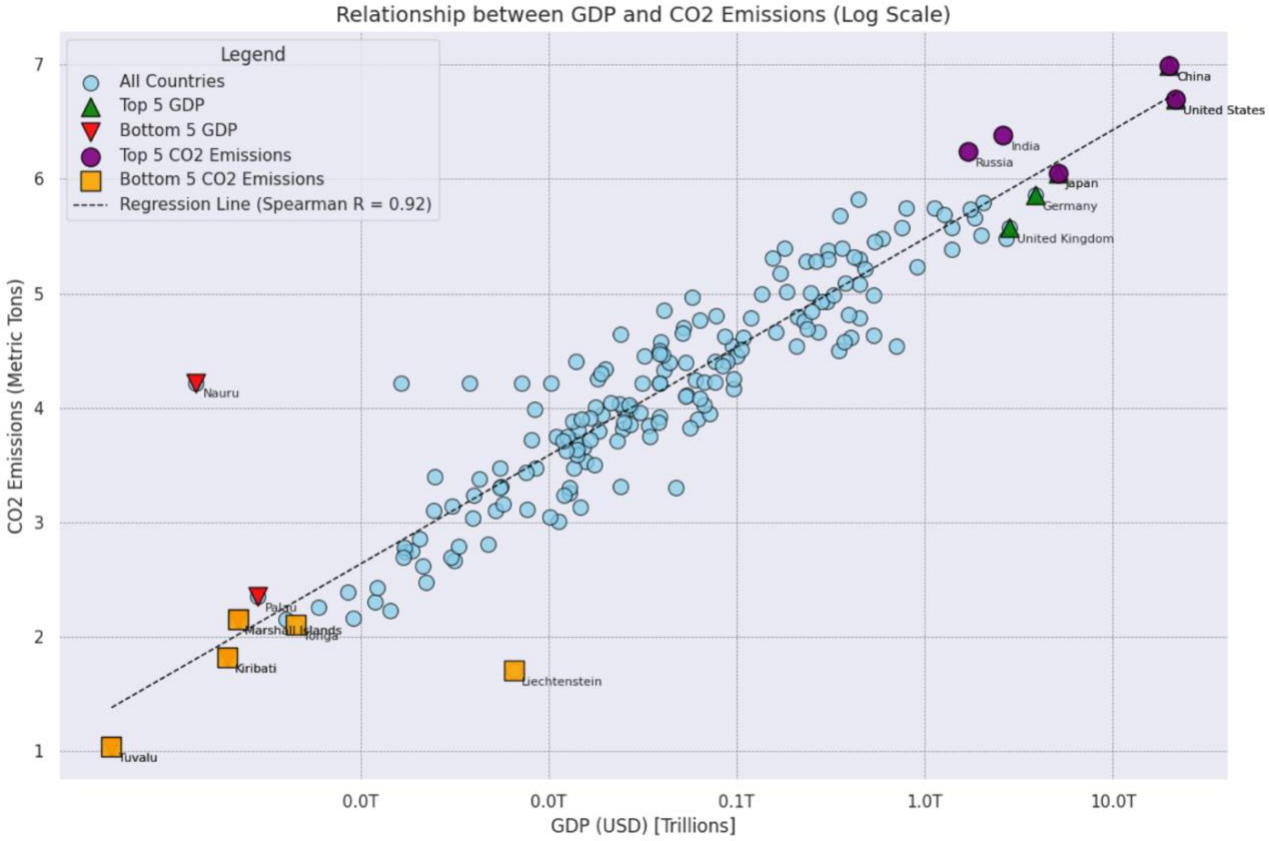
Top 5 Population

	Country	Population(2023)
73	India	1428627663
34	China	1425671352
177	United States	339996563
74	Indonesia	277534122
124	Pakistan	240485658

Bottom 5 Population

	Country	Population(2023)
141	San Marino	33642
125	Palau	18058
114	Nauru	12780
171	Tuvalu	11396
69	Vatican City	518

Graph II: GDP & CO2-Emissions



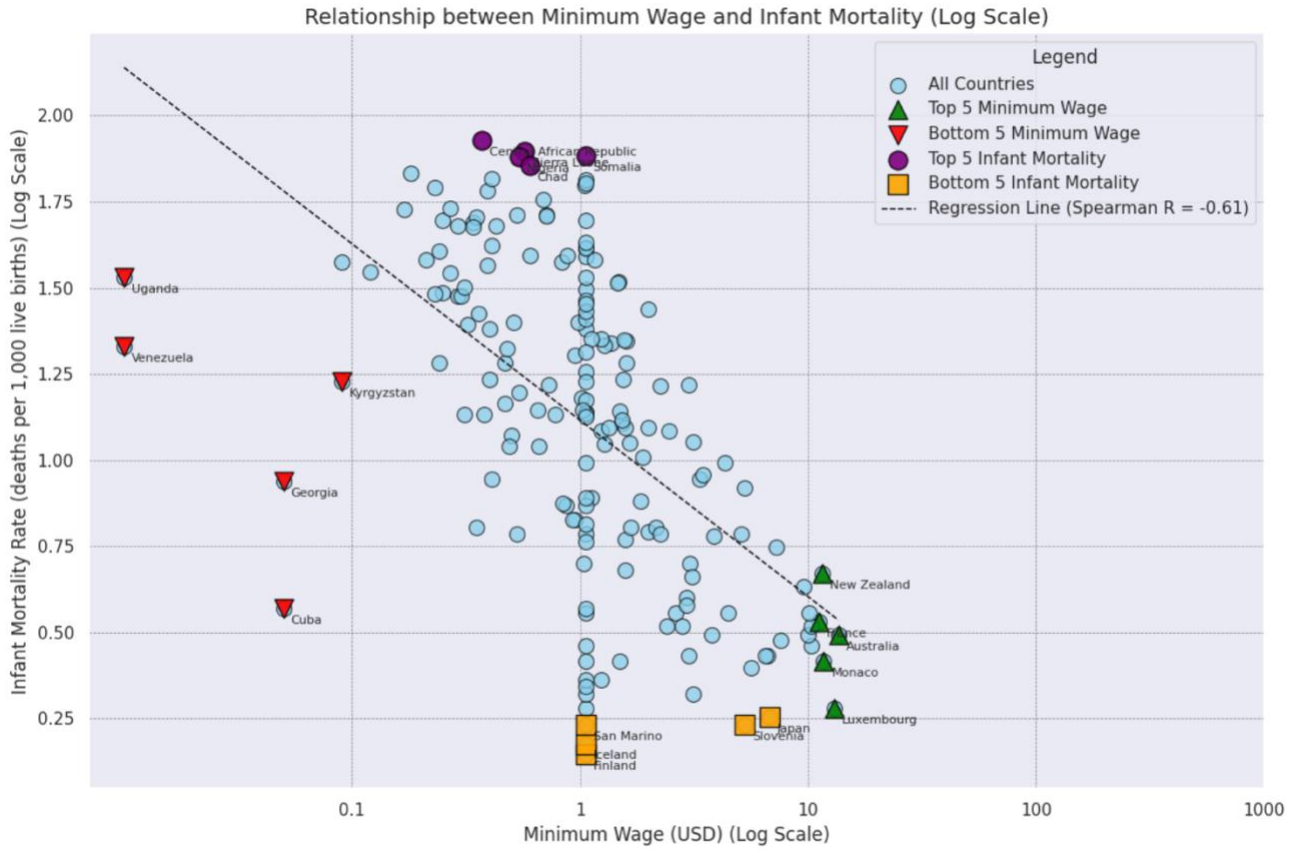
GDP and CO2 emissions have a very strong positive correlation (Spearman R = 0.92), indicating that countries with higher GDPs generally have higher CO2 emissions. This suggests a strong link between economic activity and environmental impact.

Nauru and Liechtenstein are outliers in the GDP-CO2 emissions relationship. Nauru, with low GDP but high emissions, exemplifies the environmental consequences of unsustainable resource extraction (phosphate mining) (UNEP, 2013). Conversely, Liechtenstein a high-income micro-state, boasts low CO2 emissions due to sustainable development practices (Government Principality of Liechtenstein, 2019).

Graph III: Birth Rate & Infant Mortality Rate

As the birth rate increases, there tends to be a corresponding increase in infant mortality rates, suggesting countries with higher birth rates often face higher challenges in infant survival. Countries that are clustered towards the higher end of both axes most located in West and Central Africa, underscore the need for targeted healthcare interventions and improved maternal and infant health services in these areas.

Graph IV: Scatter Plot of Infant Mortality Rate & Minimum Wage



Countries with the highest infant mortality rates, such as Sierra Leone, Nigeria, and the Central African Republic, are positioned at higher levels of infant mortality and generally lower minimum wages, illustrating the health and economic challenges in these regions. Conversely, countries with lower infant mortality rates, such as Luxembourg, Monaco, and Australia, exhibit higher minimum wages.

Table II: Top and Bottom Nations by Infant Mortality and Minimum Wage

Top 5 Infant Mortality Rate

	Country	Infant mortality
31	Central African Republic	84.5
146	Sierra Leone	78.5
151	Somalia	76.6
120	Nigeria	75.7
32	Chad	71.4

Bottom 5 Infant Mortality Rate

	Country	Infant mortality
80	Japan	1.8
141	San Marino	1.7
149	Slovenia	1.7
72	Iceland	1.5
57	Finland	1.4

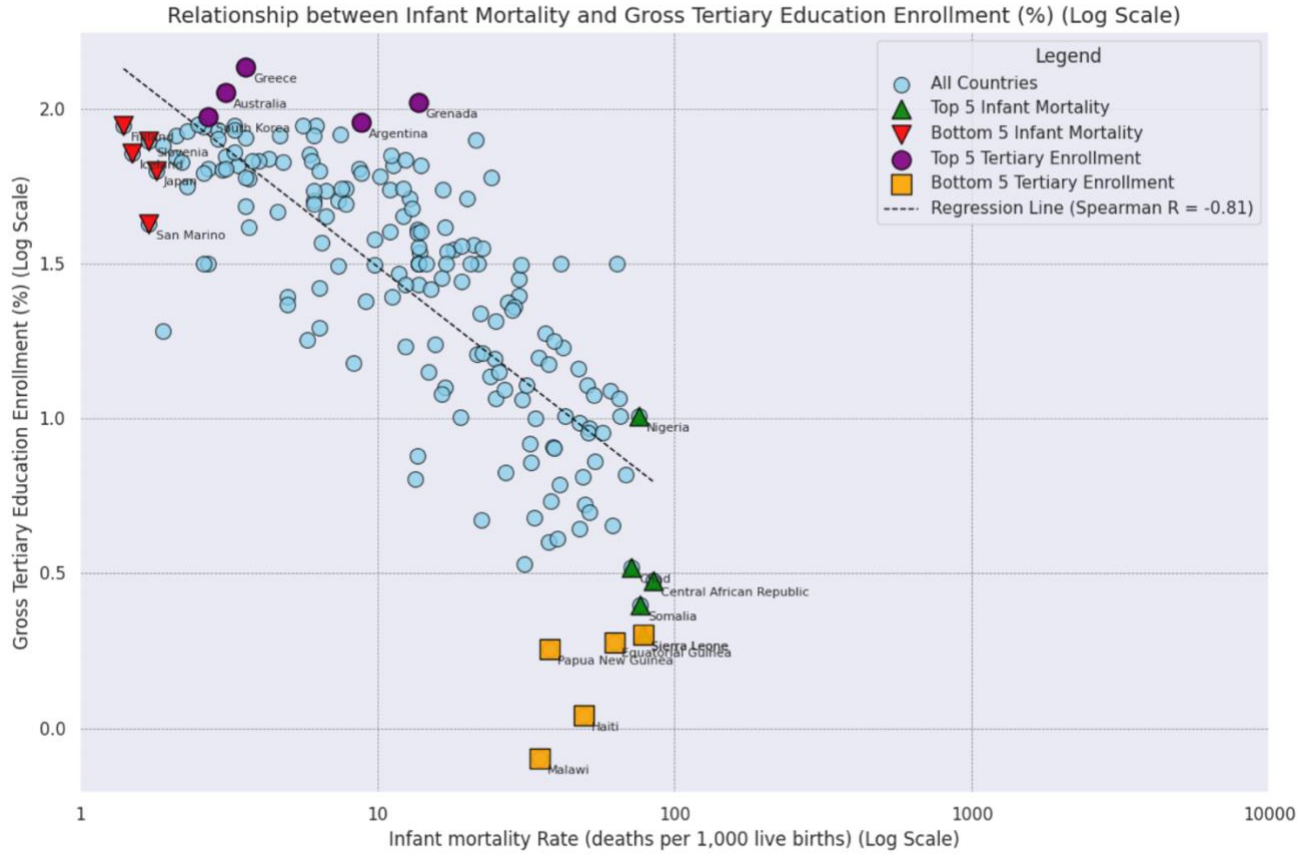
Top 5 Minimum Wage

	Country	Minimum wage
8	Australia	13.59
95	Luxembourg	13.05
107	Monaco	11.72
117	New Zealand	11.49
58	France	11.16

Bottom 5 Minimum Wage

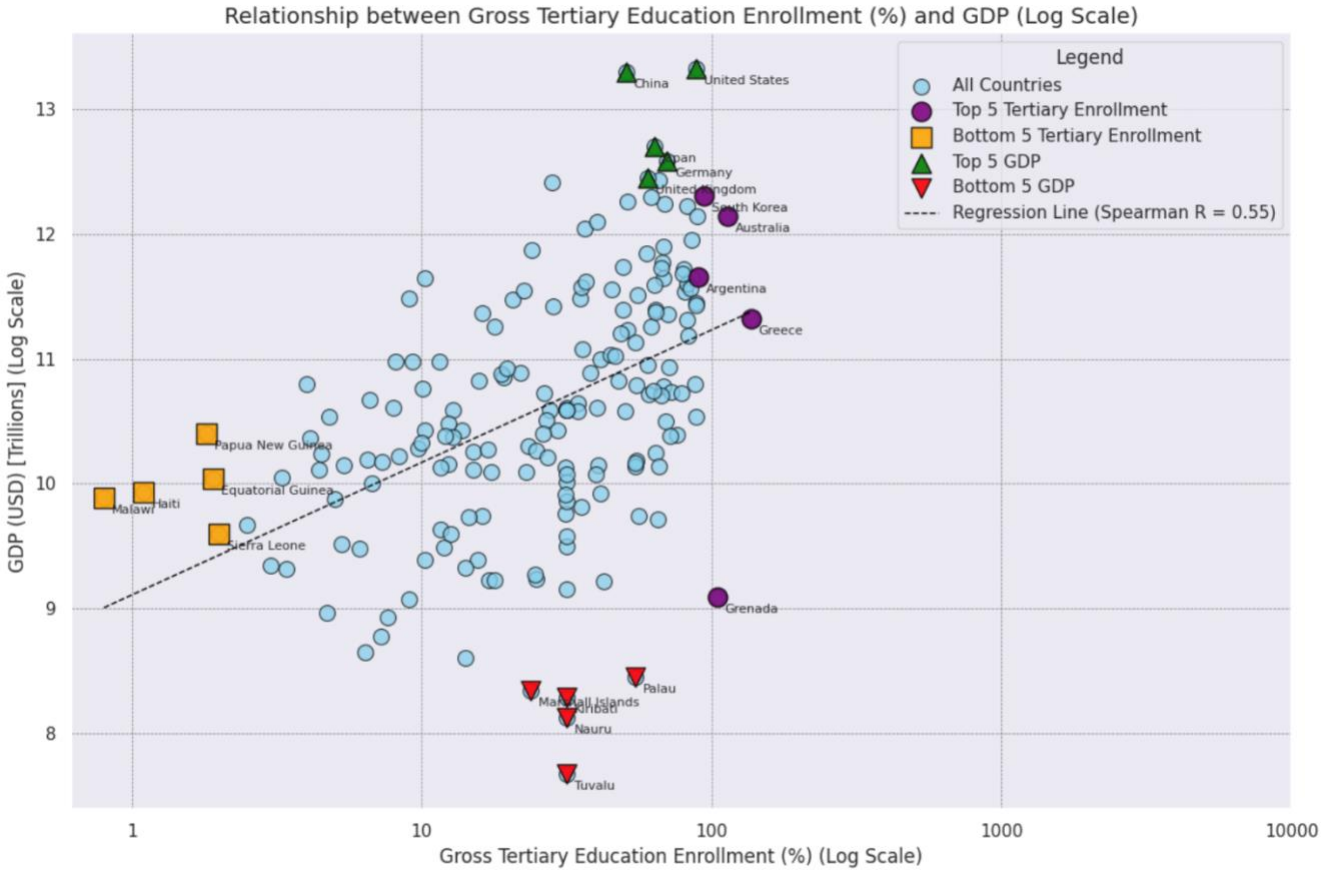
	Country	Minimum wage
176	Tanzania	0.09
60	Georgia	0.05
39	Cuba	0.05
181	Venezuela	0.01
172	Uganda	0.01

Graph V: Infant Mortality & Gross Tertiary Education Enrollment (%)



Countries with higher levels of tertiary education enrollment tend to exhibit lower rates of infant mortality. This pattern suggests that higher education may contribute to improving healthcare knowledge and practices, leading to better health outcomes. This relationship emphasises the importance of education advancements as a functional component of public health improvements and socioeconomic development.

Graph VI: Gross Tertiary Education Enrollment (%) & GDP



The countries with the top 5 tertiary education enrollment rates do not necessarily have the highest GDPs, suggesting that other factors like economic policies, technological advancements, and natural resources also play a crucial role in economic development. Several countries with very low GDP (e.g., Tuvalu, Nauru, and Burundi), have relatively high tertiary education enrollment, suggesting that education alone may not guarantee economic prosperity.

<u>Conclusions and Recommendations</u>

A prominent finding is the moderate positive correlation between population size and GDP, suggesting that a larger population can contribute to economic output. However, outliers like the U.S. and China, with very high GDPs relative to their populations, highlight the significant influence of economic reforms, technological advancements (Çalışkan, 2015; Lee, 2017), and other factors like larger urban areas

influencing GDP scales (Ribeiro et al., 2021). Interestingly, China is the "largest U.S. merchandise trading partner and biggest source of imports" which highlights the interconnected nature of their economic growth (Congressional Research Service, 2019, p. 5).

The strong positive correlation between GDP and CO_2 emissions raises concerns about the environmental impact of economic growth. To mitigate the adverse effects of climate change, policymakers should prioritize investments in green technologies, climate/green financing mechanisms, and sustainable resource management practices (Hunjra et al., 2024). The contrasting cases of Nauru and Liechtenstein further emphasize the need for sustainable resource management and the feasibility of achieving economic prosperity while minimizing environmental impact, aligning with Sustainable Development Goal (SDG) 12: Responsible Consumption and Production.

The analysis also reveals a concerning relationship between birth rate and infant mortality, particularly in regions like West and Central Africa. This highlights the urgent need for targeted healthcare interventions, improved maternal and infant health services, and socioeconomic development in these areas, aligning with SDG 3: Good Health and Well-being. Yuan et al. (2014), suggest that effective strategies include improving healthcare access through outreach programs, utilizing local healthcare workers, and offering financial or educational assistance to those in need.

The positive association between tertiary education enrollment and GDP, along with the negative correlation between tertiary education and infant mortality, underscore the importance of higher education which can lead to a more skilled workforce, better healthcare practices, and ultimately, improved socioeconomic conditions (Grant, 2017), aligning with SDG 4: Quality Education.

In conclusion, by leveraging these insights, policymakers can develop targeted interventions that promote sustainable development and improve the well-being of populations globally.

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Appendices

Appendix I: Methodology

The list below offers a structured overview of the 20 key variables, classified into three categories. Each category targets a particular dimension of national development, facilitating an organized exploration of the interconnections and influences across these variables.

Geodemographic Indicators:

- Density (P/Km²) – Population density per square kilometre.
- Agricultural Land (%) – Proportion of land used for agriculture.
- Urban Population (%) – Percentage of the population living in urban areas.
- Population (2023) – Total number of people in a country.
- Migrants (net) – Net migration rate, considering both immigration and emigration.
- Birth Rate – The number of live births per 1,000 people in a year.
- Median Age – Median age of the population.
- Armed Forces Size – Total personnel in the national military.
- Infant Mortality – Number of infant deaths per 1,0000 live births.
- Life Expectancy – Average number of years a person is expected to live.
- Fertility Rate – Average number of children a woman will have during her lifetime.

Economic Indicators:

- Gross Domestic Product (GDP) – Total economic output of a region.
- Tax Revenue (%) – Percentage of GDP collected as tax.
- Minimum Wage – Legal minimum pay per hour.
- Unemployment Rate – Percentage of the labour force that is unemployed but actively seeking employment.
- Consumer Price Index (CPI) – Measures inflation through changes in the price level of consumer goods and services.

- CO2-Emissions – Carbon dioxide emissions, are indicative of industrial activity and environmental impact.

Educational Indicators:

- Gross Primary Education Enrollment (%) – Percentage of the population enrolled in primary school.
- Gross Tertiary Education Enrollment (%) – Percentage of the population enrolled in university or institutions after secondary school.

Appendix II: Descriptive Statistics

Descriptive statistics summarize and describe relevant features of the data through quantifiable measures. They provide insight into the distribution, central tendency, and variability of data, facilitating the initial understanding of trends and anomalies within datasets (Cooksey, 2020). These statistics are fundamental in preliminary data exploration, helping to shape and guide more detailed analytical processes.

Table I: Descriptive Statistics of Variables

The table presents a statistical overview of the key dimensions across 186 countries. The data highlights significant variations in each indicator, emphasizing the disparities and development stages among these nations.

	Unemployment_Rate	Population(2023)	Migrants(net)	Fert.Rate	Med.Age	UrbanPop %	Density(P/Km2)
count	186	186	186	186	186	186	186
mean	6.119623656	42783405.52	-426.2688172	2.499462366	30.13978495	59.11290323	366.8494624
std	5.197125751	153030055.1	190573.7084	1.193654272	9.464118751	21.67382642	2029.909725
min	0	518	-910475	0.9	15	12	2
25%	2.505	2356880	-12970.75	1.6	22	41	34.25
50%	4.59	9830207	-2000	2.1	29	60	88
75%	8.415	34065827.25	887.5	3.175	39	77.75	214
max	28.18	1428627663	1784718	6.7	54	99	26337
	Birth Rate	**Co2-Emissions**	**CPI**	**GDP**	**Gross primary education enrollment (%)**	**Gross tertiary educ**	**Armed Forces size**
count	186	186	186	186	186	186	186
mean	19.86672043	180052.543	187.7263978	4.93171E+11	102.2811828	38.02903226	150037.6344
std	9.688644482	843035.2754	389.4112562	2.21115E+12	13.12072924	28.22623786	366157.5701
min	5.9	11	99.03	47271463	23.4	0.8	0
25%	11.075	3044.75	115.35	11098819045	99.075	12.8	15250
50%	17.87	16590	126.6	38667268091	102.4	31.55	33000
75%	27.0925	64738.75	155.6425	2.36788E+11	107.475	61.4	128250
max	46.08	9893038	4583.71	2.14277E+13	142.5	136.6	3031000
	Infant mortality	**Life expectancy**	**Minimum wage**	**Tax revenue (%)**	**Agricultural Land(%)**	**Land Area(Km2)**	
count	186	186	186	186	186	186	
mean	20.73494624	72.56290323	1.925	16.61290323	38.88924731	715759.5484	
std	19.24724801	7.246573853	2.616590674	6.522563346	21.5125681	1958255.277	
min	1.4	52.8	0.01	0	0.6	0	
25%	6.025	67.725	0.5325	12.8	21.9	27770	
50%	13.7	73.85	1.055	16.4	39.5	131957	
75%	30.55	77.375	1.6375	20.625	54.525	581389.25	
max	84.5	85.4	13.59	37.2	82.6	17098240	

Appendix III: Sustainable Development Goals (*United Nations Sustainable Development Goals, 2018***)**

Table II: Skewness and Kurtosis Analysis

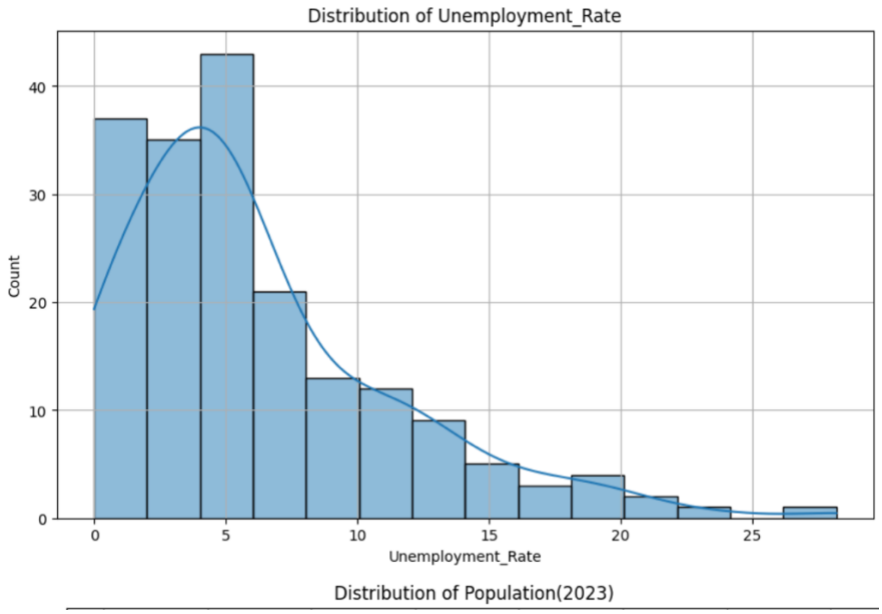
	Skewness
Unemployment_Rate	1.339854985
Population(2023)	8.178577335
Migrants(net)	4.875499889
Fert.Rate	1.234626712
Med.Age	0.155710959
UrbanPop %	-0.25578922
Density(P/Km2)	11.78350704
Agricultural Land(%)	0.10782806
Land Area(Km2)	5.453504821
Armed Forces size	5.341788209
Birth Rate	0.651259555
Co2-Emissions	9.524715051
CPI	9.544861262
GDP	8.422847431
Gross primary education enrollment (%)	-0.983546178
Gross tertiary education enrollment (%)	0.668518411
Infant mortality	1.256162734
Life expectancy	-0.603801503
Minimum wage	2.697201621
Tax revenue (%)	0.091374833

	Kurtosis
Unemployment_Rate	1.99889503
Population(2023)	71.89597596
Migrants(net)	48.9378928
Fert.Rate	1.083696927
Med.Age	-1.104597386
UrbanPop %	-0.846981557
Density(P/Km2)	147.8913924
Agricultural Land(%)	-0.84837447
Land Area(Km2)	34.46860452
Armed Forces size	34.19124643
Birth Rate	-0.618016982
Co2-Emissions	101.6859522
CPI	98.37725289
GDP	75.17232597
Gross primary education enrollment (%)	8.119523502
Gross tertiary education enrollment (%)	-0.276131669
Infant mortality	0.881045713
Life expectancy	-0.166491948
Minimum wage	7.07000311
Tax revenue (%)	0.573905478

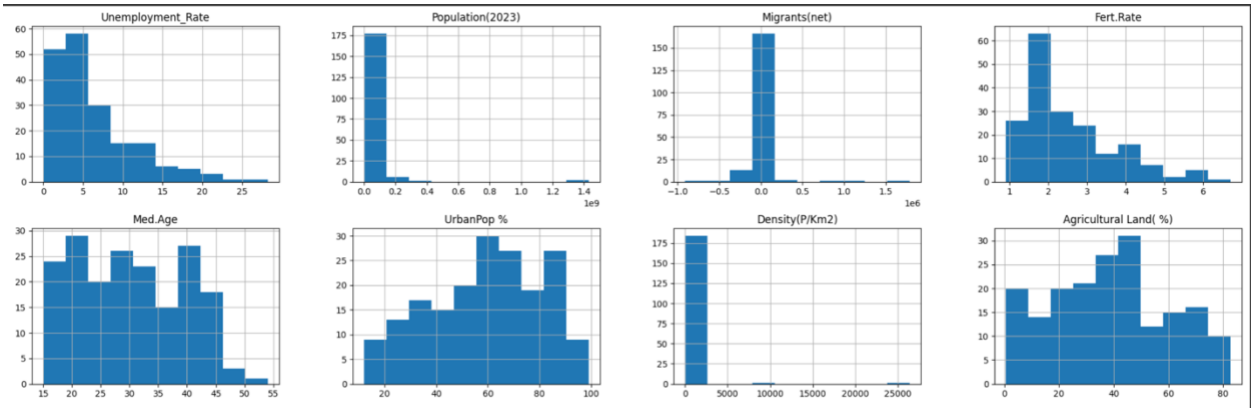
Appendix IV: Understanding Correlation Coefficient

A coefficient of +1 signifies a perfect positive correlation, where an increase in one variable results in a proportional increase in the other (Nickolas et al., 2023). Conversely, a coefficient of -1 indicates a perfect negative correlation, where an increase in one variable results in a proportional decrease in the other. Additionally, a coefficient of 0 means there is no linear relationship between the variables.

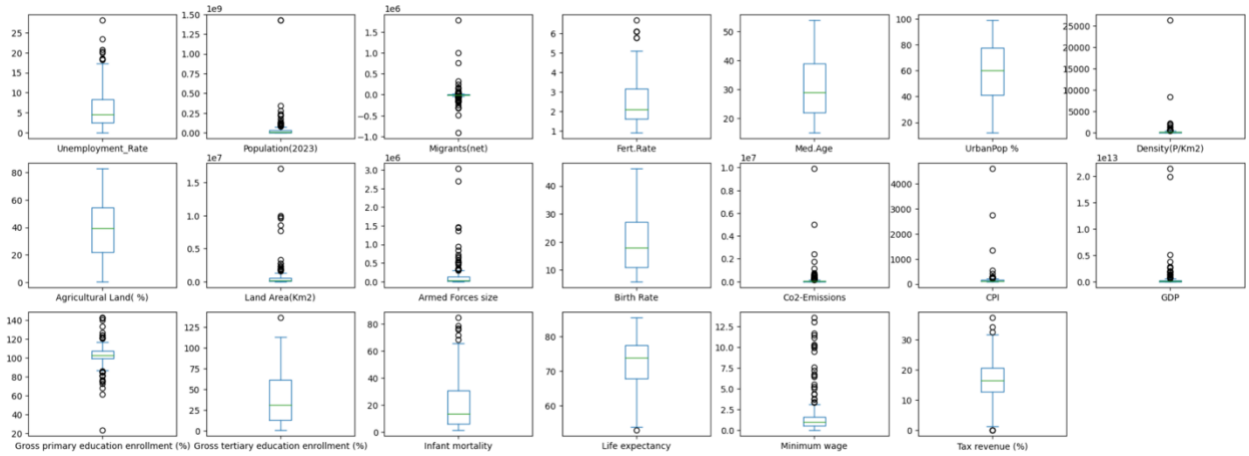
Graph I: Statistical Distribution Graph (Example)



Graph II: Histograms



Graph III: Box Plots



Appendix V: Global Education CSV File (ELGIRIYEWITHANA, 2023a)

Global_Education.csv (21.64 kB)

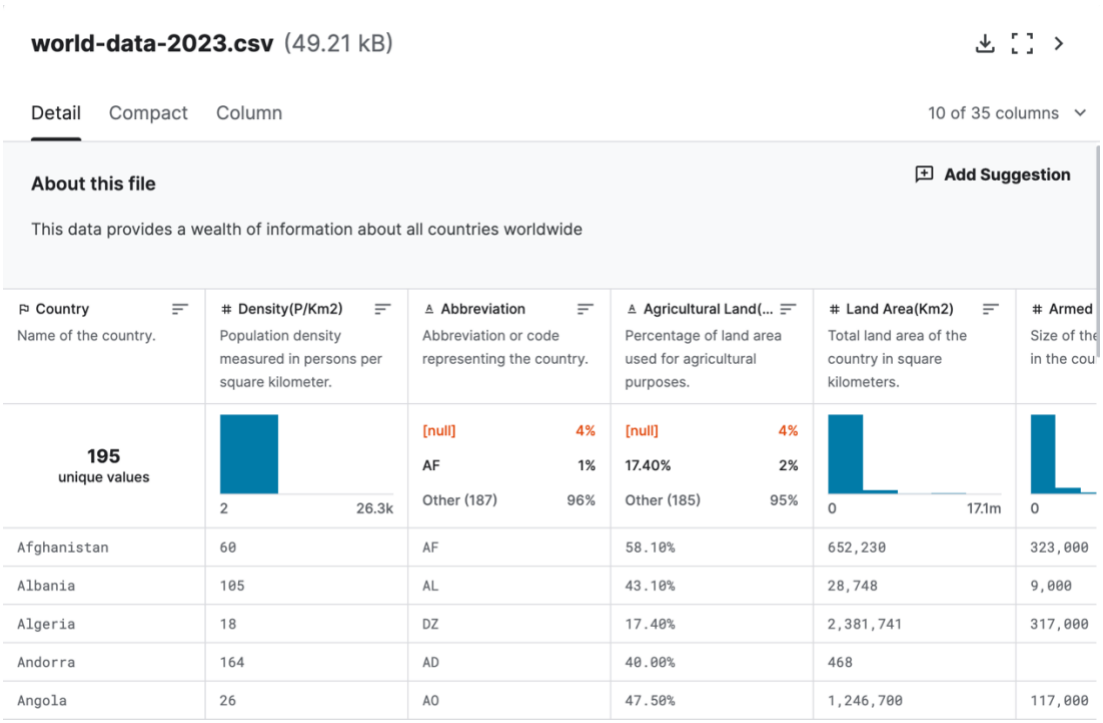
Detail Compact Column 10 of 29 columns

About this file

This dataset provides a comprehensive global perspective on education, offering vital insights into diverse education systems worldwide. It covers essential metrics like out-of-school rates, completion rates, proficiency levels, literacy rates, birth rates, and enrollment in primary and tertiary education. It's a valuable resource for researchers, educators, and policymakers looking to assess and improve education systems globally.

Countries and are...	Latitude	Longitude	OOSR_Pre0Prima...	OOSR_Pre0Prima...	OOSR_I
Name of the countries and areas.	Latitude coordinates of the geographical location.	Longitude coordinates of the geographical location.	Out-of-school rate for pre-primary age males.	Out-of-school rate for pre-primary age females.	Out-of-scl primary ag
202 unique values	0.02 65	0.82 178	0 96	0 96	0
Afghanistan	33.93911	67.709953	0	0	0
Albania	41.153332	20.168331	4	2	6
Algeria	28.033886	1.659626	0	0	0
Andorra	42.506285	1.521801	0	0	0

Appendix VI: World Data CSV File (ELGIRIYEWITHANA, 2023b)



world-data-2023.csv (49.21 kB)

Detail Compact Column — 10 of 35 columns

About this file — Add Suggestion

This data provides a wealth of information about all countries worldwide

Country Name of the country.	# Density(P/Km2) Population density measured in persons per square kilometer.	Abbreviation Abbreviation or code representing the country.	Agricultural Land(... Percentage of land area used for agricultural purposes.	# Land Area(Km2) Total land area of the country in square kilometers.	# Armed Size of the in the cou
195 unique values	2 – 26.3k	[null] 4% AF 1% Other (187) 96%	[null] 4% 17.40% 2% Other (185) 95%	0 – 17.1m	0
Afghanistan	60	AF	58.10%	652,230	323,000
Albania	105	AL	43.10%	28,748	9,000
Algeria	18	DZ	17.40%	2,381,741	317,000
Andorra	164	AD	40.00%	468	
Angola	26	AO	47.50%	1,246,700	117,000

Appendix VII: World Population CSV File (U.N. Revision, 2023)

#	Country (or dependency)	Population (2023)	Yearly Change	Net Change	Density (P/Km²)	Land Area (Km²)	Migrants (net)	Fert. Rate	Med. Age	Urban Pop %	World Share
1	India	**1,428,627,663**	0.81 %	11,454,490	481	2,973,190	-486,136	2.0	28	36 %	17.76 %
2	China	**1,425,671,352**	-0.02 %	-215,985	152	9,388,211	-310,220	1.2	39	65 %	17.72 %
3	United States	**339,996,563**	0.50 %	1,706,706	37	9,147,420	999,700	1.7	38	83 %	4.23 %
4	Indonesia	**277,534,122**	0.74 %	2,032,783	153	1,811,570	-49,997	2.1	30	59 %	3.45 %
5	Pakistan	**240,485,658**	1.98 %	4,660,796	312	770,880	-165,988	3.3	21	35 %	2.99 %
6	Nigeria	**223,804,632**	2.41 %	5,263,420	246	910,770	-59,996	5.1	17	54 %	2.78 %
7	Brazil	**216,422,446**	0.52 %	1,108,948	26	8,358,140	6,000	1.6	34	88 %	2.69 %
8	Bangladesh	**172,954,319**	1.03 %	1,767,947	1,329	130,170	-309,977	1.9	27	41 %	2.15 %
9	Russia	**144,444,359**	-0.19 %	-268,955	9	16,376,870	-136,414	1.5	39	75 %	1.80 %
10	Mexico	**128,455,567**	0.75 %	951,442	66	1,943,950	-50,239	1.8	30	88 %	1.60 %
11	Ethiopia	**126,527,060**	2.55 %	3,147,136	127	1,000,000	-11,999	4.0	19	22 %	1.57 %
12	Japan	**123,294,513**	-0.53 %	-657,179	338	364,555	99,994	1.3	49	94 %	1.53 %
13	Philippines	**117,337,368**	1.54 %	1,778,359	394	298,170	-69,996	2.7	25	47 %	1.46 %
14	Egypt	**112,716,598**	1.56 %	1,726,495	113	995,450	-29,998	2.8	24	41 %	1.40 %