**Assignment: Country-Wise CO₂ Emissions Statistical Analysis (1970–2020)**

**Objective**

Analyze and compare CO₂ emissions data for the world's top 10 economies over the five decades from 1970 to 2020. Apply statistical methods to gain insights into emission patterns and variability, and present your findings in a clear, comparative format.

**Assignment Instructions**

**1. Data Preparation**

* Obtain a dataset of annual CO₂ emissions (country-wise, from the excel file given to you) and GDP data for countries for the period 1970–2020.
* Identify the top 10 countries by GDP, using GDP figures from around 1970 for consistency across the time period
* Filter the emissions dataset to include only these 10 countries.

**2. Selecting the Time Frame**

* Use emission data at decade intervals: 1970-80, 1980-90 and so on till 2020.
* Ensure all selected countries have valid data for all these years.

**3. Data Analysis**

For each of the 10 countries:

* Extract annual CO₂ emissions for the 5 selected decade.
* Calculate the following statistics using the extracted data:
  + **Mean (Average) CO₂ emissions**
  + **Emission variance**
  + **Standard deviation**
  + **Minimum emission value**
  + **Maximum emission value**
* Structure your results in a summary table (see format below).

**4. Table Format**

Complete your table as follows (fill with your calculated values): Decade 1970-1980

| **Country** | **Mean CO₂ Emission** | **Variance** | **Standard Deviation** | **Minimum** | **Maximum** |
| --- | --- | --- | --- | --- | --- |
| United States |  |  |  |  |  |
| USSR/Russia |  |  |  |  |  |
| Germany |  |  |  |  |  |
| Japan |  |  |  |  |  |
| France |  |  |  |  |  |
| United Kingdom |  |  |  |  |  |
| Italy |  |  |  |  |  |
| China |  |  |  |  |  |
| Canada |  |  |  |  |  |
| India |  |  |  |  |  |

Complete your table as follows (fill with your calculated values): Decade 1980-1990

| **Country** | **Mean CO₂ Emission** | **Variance** | **Standard Deviation** | **Minimum** | **Maximum** |
| --- | --- | --- | --- | --- | --- |
| United States |  |  |  |  |  |
| USSR/Russia |  |  |  |  |  |
| Germany |  |  |  |  |  |
| Japan |  |  |  |  |  |
| France |  |  |  |  |  |
| United Kingdom |  |  |  |  |  |
| Italy |  |  |  |  |  |
| China |  |  |  |  |  |
| Canada |  |  |  |  |  |
| India |  |  |  |  |  |

**5. Interpretation and Reporting**

* Briefly interpret your results:
  + Discuss which country had the highest/lowest mean emissions.
  + Comment on the countries with the largest and smallest emission variability.
  + Identify any noticeable trends over time or outlier years.
* Suggest possible reasons for observed differences (economic changes, policy, industrialization).

**6. Submission**

* Excel file.
* Submit a concise report (2–5 pages) featuring explanations, your summary table, and interpretative comments.
* Consider including graphs or charts for visualization

**Evaluation Criteria**

* Correctness and completeness of calculations.
* Clear, organized presentation and adherence to the required table format.
* Depth and clarity of interpretation.

**Note:** Ensure all statistical calculations use the same time points (1970, 1980, 1990, 2000, 2010, and 2020) for all countries to allow a fair comparison. Address missing data transparently—either by cleaning your dataset or clearly noting omissions.

**Statistical Analysis of CO2 Emission of Each Country Standing (1970-2020)**

**Chart Overview**

This chart presents the cumulative percentage of global CO₂ emissions attributed to major countries over a 50-year period. It highlights long-term contributions rather than current annual emissions.

**Country-Wise Analysis**

**1. United States – 45%**

* The largest contributor by far.
* Reflects decades of high industrial activity, energy consumption, and reliance on fossil fuels.
* Indicates the historical dominance of the U.S. in global economic and manufacturing output.

**2. Russia – 13%**

* Second-highest share.
* Emissions were elevated during the Soviet era due to heavy industry and energy production.
* Continued fossil fuel reliance sustains its contribution.

**3. Germany – 10%**

* Significant historical emissions from coal-based industries.
* Despite recent environmental reforms, legacy emissions remain substantial.

**4. United Kingdom – 8%**

* Early industrialization led to high historical emissions.
* Recent decades show decline due to deindustrialization and renewable energy adoption.

**5. Japan – 7%**

* Post-war economic expansion drove energy demand.
* Limited domestic fossil resources led to high import-based emissions.

**6. India – 6%**

* Lower cumulative share despite large population.
* Reflects later industrialization and lower per capita emissions.
* Emissions have increased significantly in recent years.

**7. France – 4%**

* Among the lowest contributors.
* Early adoption of nuclear energy reduced fossil fuel dependence.
* Stable energy policy kept emissions consistently low.

**8. Canada – 4%**

* High emissions relative to population size.
* Driven by energy-intensive industries and oil extraction activities.

**9. Unlabelled Segment – 3%**

* Likely represents smaller economies or aggregated data.
* Indicates minor contributors to global emissions in this dataset.

**Key Insights**

* **Historical Responsibility**: Developed nations like the U.S., UK, and Germany have disproportionately high cumulative emissions due to early and sustained industrialization.
* **Energy Strategy Impact**: France’s low share demonstrates the long-term effect of nuclear energy adoption.
* **Population vs. Emissions**: India’s relatively low share highlights the difference between total population and per capita emissions.
* **Economic Structure**: Countries with resource-heavy industries (e.g., Canada, Russia) show elevated emissions despite smaller populations.

. **Statistical Analysis of CO2 Emission of Each Country Standing Top 10 in their Respective decades between 1970-2020**

**1970-1980**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Country** | **Mean C02 Emission Value** | **Max Value** | **Min Value** | **Standard deviation** | **Variance** |
| **United States** | 4687380727 | 5008955400 | 4339686000 | 228637103.7 | 5.22749E+16 |
| **Russia** | 1809057709 | 2129468500 | 1440773200 | 227864204.5 | 5.19221E+16 |
| **Japan** | 889509658.2 | 957130200 | 769740300 | 59720137.59 | 3.56649E+15 |
| **Germany** | 1063289827 | 1117888300 | 1002447000 | 34938449.68 | 1.2207E+15 |
| **France** | 511241389.1 | 539771650 | 461337700 | 23485066.38 | 5.51548E+14 |
| **United Kingdom** | 624740821.8 | 660388200 | 579035400 | 28816697.42 | 8.30402E+14 |
| **Italy** | 350134649.1 | 386433020 | 296364540 | 28842030.79 | 8.31863E+14 |
| **Canada** | 395339831.8 | 442846850 | 341177200 | 31955003.63 | 1.02112E+15 |
| **China** | 1180509332 | 1525661200 | 807952640 | 255582239.9 | 6.53223E+16 |
| **India** | 233703287.3 | 291711100 | 181722640 | 36213656.8 | 1.31143E+15 |
|  |  |  |  |  |  |

The United States had the highest mean CO2 emissions, while India had the lowest among the listed countries. China exhibited the greatest emission variability, whereas France showed the smallest variability. Based on the emission values and variances, some clear trends and potential outlier years can be discussed.

**Highest and Lowest Mean Emissions**

* **Highest:** United States led with a mean emission value of 4,687,380,727, indicating its significant contribution to global CO2 emissions over time.
* **Lowest:** India had the lowest mean emission value at 2,337,032,87.3, reflecting its relatively smaller emissions compared to the other major nations listed.

**Largest and Smallest Emission Variability**

* **Largest Variability:** China stands out with the largest variance (6.52322×10166.52322×1016), paired with a large standard deviation (2,555,823,329.5), suggesting substantial fluctuation in yearly emission values.
* **Smallest Variability:** France has the smallest variance (5.51548×10145.51548×1014) and a low standard deviation (23,485,066.38), implying its emissions have remained relatively consistent over the measured period.

**Noticeable Trends and Outlier Years**

* **Trends:** Most developed countries (United States, Russia, Japan, Germany, United Kingdom, France, Italy, Canada) have higher mean values but moderate variability, indicating stable but high emissions. China, however, displays rapid changes, possibly due to industrialization and economic growth.
* **Outliers:** China's max and min values (1,525,621,600 and 807,952,640 respectively) highlight possible outlier years with exceptional jumps in emissions. The large difference between max and min suggests uneven emission patterns or policy shifts.

Overall, established economies show sustained emission levels, while emerging economies such as China show rapid changes and higher volatility.

**1980-1990**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Country** | **Mean CO2 Emission Value** | **MAX Value** | **MIN Value** | **Standard Deviation** | **Variance** |
| **United States** | 4771131118 | 5132543500 | 4429711000 | 245225083.2 | 6.01353E+16 |
| **Japan** | 954492970.9 | 1157393200 | 884419900 | 78145793.26 | 6.10677E+15 |
| **Russia** | 2283294582 | 2536247800 | 2088922600 | 151225920.3 | 2.28693E+16 |
| **Germany** | 1038710722 | 1100066000 | 1008792400 | 25585630.75 | 6.54625E+14 |
| **France** | 419914740 | 512217540 | 386506080 | 38532256.13 | 1.48473E+15 |
| **Italy** | 381163829.1 | 438207000 | 358409100 | 23159981.74 | 5.36385E+14 |
| **United Kingdom** | 565098856.4 | 601945100 | 529108160 | 19799677.34 | 3.92027E+14 |
| **Canada** | 432225560 | 462885150 | 404707940 | 20195764.87 | 4.07869E+14 |
| **China** | 1986459200 | 2484854800 | 1476487800 | 388417016.9 | 1.50868E+17 |
| **India** | 412309033.6 | 577996000 | 291711100 | 95002612.68 | 9.0255E+15 |
|  |  |  |  |  |  |

The United States had the highest mean CO2 emission value, while India had the lowest among the countries listed. China exhibited the largest emission variability, and Germany had the smallest variability in emissions. Below are the findings based on the provided data.

**Highest** and **Lowest** Mean Emissions

* The **United States** had the highest mean CO2 emissions at **4,771,131,118.**
* India had the lowest mean CO2 emissions at **412,309,033.6**.

Largest and Smallest Emission Variability

* China showed the largest emission variability, with the highest standard deviation) **(3,884,170,16.9** and variance **(1.50868E+17),** indicating large fluctuations in emissions over time.
* Germany had the smallest variability, with the lowest variance (6.54625E+14) and a standard deviation of **25,585,630.75**, suggesting stable emissions year to year.

Noticeable Trends and Outlier Years

* The **United States, Japan, and Russia** also had high mean values but comparatively lower variability than **China**, showing more stable trends despite high emission volumes.
* **China's** high maximum and minimum values, along with large variance, point to outlier years or major shifts, likely due to phases of rapid industrialization or policy changes.
* The data suggests more stable emissions in most developed nations, with notable volatility primarily in rapidly developing economies like China.

**1990-2000**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Country** | **Mean CO2 Emission Value** | **MAX value** | **MAX value** | **Standard deviation** | **Variance** |
| **United States** | 5478999100 | 6010135600 | 5062956500 | 310925602.6 | 9.66747E+16 |
| **Japan** | 1213566509 | 1263993200 | 1157393200 | 38337547.89 | 1.46977E+15 |
| **Russia** | 1777388191 | 2536247800 | 1465253400 | 380449049.1 | 1.44741E+17 |
| **Germany** | 953895607.3 | 1054795900 | 895442050 | 47568033.5 | 2.26272E+15 |
| **France** | 400146780.9 | 417859100 | 380793060 | 12338900.84 | 1.52248E+14 |
| **Italy** | 445871860.9 | 469596930 | 424506020 | 14434833.6 | 2.08364E+14 |
| **United Kingdom** | 579426173.6 | 609412700 | 561649600 | 16417264.33 | 2.69527E+14 |
| **China** | 3164024227 | 3649226500 | 2484854800 | 416467986.3 | 1.73446E+17 |
| **Canada** | 497725938.2 | 566261400 | 449756130 | 38878554.93 | 1.51154E+15 |
| **India** | 773204050.9 | 986444700 | 577996000 | 138075340.2 | 1.90648E+16 |

The United States had the highest mean CO2 emission value, while India had the lowest. China demonstrated the greatest emission variability, and France had the smallest emission variability. The following points summarize the trends based on the presented data.

**Highest and Lowest Mean Emissions**

* **Highest:** The United States had the highest mean CO2 emissions with a value of 5,478,999,100.
* **Lowest:** India had the lowest mean CO2 emissions at 773,204,050.9.

**Largest and Smallest Emission Variability**

* **Largest Variability:** China had the largest emission variability, with a variance of 1.73446×10171.73446×1017 and a standard deviation of 4,164,679,86.3, indicating significant fluctuations in emission values over time.
* **Smallest Variability:** France experienced the smallest emission variability, with the lowest variance (1.52248×10141.52248×1014) and a standard deviation of 12,333,900.84, showing relatively stable emissions throughout the period.

**Noticeable Trends and Outlier Years**

* Most developed countries such as the United States, Japan, and Germany reported high mean emissions but exhibited much less variability than China, suggesting relatively stable emissions historically.
* China and India both displayed substantial differences between minimum and maximum emission values, signalling outlier years or periods of rapid increases. This reflects the impact of rapid development and changing policies in these emerging economies.
* France stands out for its consistently low variability, indicating more predictable and stable emission trends.

This analysis shows that emissions are highest and most stable in long-industrialized countries, while rapidly industrializing nations like China and India experience the most variability and outlier years.

**2000 – 2010**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Country** | **Mean CO2 Emission Value** | **Max value** | **Max Value** | **Standard Deviation** | **Variation** |
| **United States** | 5943412264 | 6132183000 | 5480725500 | 201415250.3 | 4.05681E+16 |
| **Japan** | 1257613191 | 1302996200 | 1163392600 | 40835954.78 | 1.66758E+15 |
| **Germany** | 868891350.9 | 915254800 | 789950700 | 36956525.55 | 1.36578E+15 |
| **United Kingdom** | 554638276.4 | 577970560 | 494107700 | 27302688.67 | 7.45437E+14 |
| **China** | 5901126164 | 8620576000 | 3649226500 | 1733665532 | 3.0056E+18 |
| **France** | 400205881.8 | 415795070 | 370875840 | 15259740.58 | 2.3286E+14 |
| **Italy** | 476091800 | 501364060 | 424061120 | 25707284.06 | 6.60864E+14 |
| **Canada** | 568594290 | 591888640 | 542810750 | 13651640.28 | 1.86367E+14 |
| **India** | 1261749969 | 1677337200 | 986444700 | 249136399.5 | 6.20689E+16 |
| **Russia** | 1565617736 | 1652064500 | 1479142400 | 58151698.86 | 3.38162E+15 |

**Economic Transformation and Industrialization:**

* **China and India:** The immense growth in emissions and their high variability are directly linked to their rapid industrialization and economic expansion. As these nations continue to develop, their energy demand, largely met by fossil fuels, has driven up their carbon footprint. However, recent years have seen significant investments in renewable energy, leading to a more complex and variable emissions pattern.
* **United States:** As a long-established industrial powerhouse, the U.S. has historically high emissions. While there has been a gradual shift away from coal and an increase in natural gas and renewables, its large economy and high energy consumption per capita keep its mean emissions at the top.
* **United Kingdom:** The UK's lower and more stable emissions are a direct consequence of its post-industrial economic transition. The decline of coal mining and heavy industry, coupled with a deliberate policy to expand renewable energy, has led to a significant and consistent reduction in its carbon output.

**Energy Policies and Technological Choices:**

* **France:** The country's early and extensive adoption of **nuclear energy** is the primary reason for its low per capita emissions compared to other industrialized nations. This strategic choice has largely decarbonized its electricity sector.
* **Germany:** Germany's "Energiewende" (energy transition) policy presents a mixed picture. While there is a strong commitment to renewables, the phase-out of nuclear power has, at times, led to an increased reliance on coal, impacting its emission reduction trajectory.
* **Canada:** The exploitation of **oil sands** contributes significantly to Canada's emissions profile, presenting a major challenge to its climate targets despite a relatively clean electricity grid in some provinces due to hydropower.

**Historical and Political Events:**

* **Russia:** The dissolution of the Soviet Union in 1991 led to a sharp economic contraction and a subsequent significant drop in CO2 emissions. In the post-Soviet era, its emissions have been influenced by the transition to a market economy and its heavy reliance on its vast oil and gas reserves.
* **Japan:** Following the Fukushima nuclear disaster in 2011, Japan shut down most of its nuclear reactors, leading to an increased reliance on imported fossil fuels and a subsequent rise in emissions. Efforts to restart reactors and expand renewables are ongoing to reverse this trend.

**2010 – 2020**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Country** | **Mean CO2 Emission Value** | **MAX value** | **MIN value** | **Standard Deviation** | **Variance** |
| **United States** | 5343172000 | 5679715300 | 4714628000 | 252363735.9 | 6.36875E+16 |
| **China** | 9951270000 | 10905693000 | 8620576000 | 605148201.9 | 3.66204E+17 |
| **Japan** | 1206091473 | 1315297800 | 1040483400 | 84263325.88 | 7.10031E+15 |
| **Germany** | 779207951.8 | 831742850 | 648356860 | 54957418.85 | 3.02032E+15 |
| **India** | 2195833936 | 2612888000 | 1677337200 | 321380074.5 | 1.03285E+17 |
| **United Kingdom** | 424137936.4 | 511904580 | 326263200 | 58232252.39 | 3.391E+15 |
| **France** | 335732110 | 376457200 | 280490020 | 25951645.16 | 6.73488E+14 |
| **Italy** | 367754220 | 435710340 | 302602430 | 38897214.62 | 1.51299E+15 |
| **Russia** | 1662772155 | 1712494300 | 1632783200 | 32332900.27 | 1.04542E+15 |
| **Canada** | 563582055.5 | 582024960 | 526581600 | 14583899.41 | 2.1269E+14 |

**CO2 Emissions Overview by Country**

**• China – Highest Average Emissions**  
China leads in average carbon dioxide emissions due to its vast industrial base. As the world's largest manufacturer, it consumes enormous amounts of energy, primarily from coal and other fossil fuels. This energy demand is driven by exports, infrastructure development, and urbanization, making China the top emitter globally.

**• France – Lowest Average Emissions**  
France consistently ranks lowest among major economies in CO₂ emissions. This is largely attributed to its energy strategy, where nuclear power accounts for over 70% of electricity generation. By minimizing reliance on coal and natural gas, France maintains a low carbon footprint despite being a developed nation.

**Emissions Variability**

**• China – Highest Variability**  
China exhibits the greatest fluctuations in emissions over time. This variability is a result of rapid economic cycles, shifts in industrial output, and changes in energy policy. Periods of intense growth, followed by regulatory adjustments or global market shifts, cause significant swings in its carbon output.

**• France – Lowest Variability**  
France shows the most consistent emissions profile, with minimal year-to-year changes. Its stable reliance on nuclear energy and controlled industrial expansion contribute to this predictability. The country’s long-term energy planning ensures that emissions remain steady regardless of economic conditions.

**Factors Influencing Emissions Differences**

**• Industrialization Level**

* **China**: Underwent aggressive industrialization, transforming from an agrarian economy to a global manufacturing hub. This transition required massive energy inputs, leading to high emissions and variability.
* **India**: Following a similar path, India’s growing infrastructure and energy needs result in elevated emissions, though still below China’s levels.

**• Economic Maturity**

* **United States, Germany, United Kingdom**: These countries have mature economies with established industrial sectors. While emissions remain high due to legacy infrastructure and consumption patterns, the rate of change is slower. Their emissions are more stable, reflecting a plateau in industrial growth.

**• Energy Policy**

* **France**: Adopted nuclear energy early, reducing dependence on fossil fuels. This strategic choice has led to low emissions and high consistency.
* **United States & Germany**: Both are transitioning toward renewable energy but still rely significantly on coal, oil, and natural gas. This mix creates moderate variability in emissions as policies and technologies evolve.

**Summary**

**• Emerging Economies** – Countries like China and India show high emissions and variability due to rapid industrial growth and evolving energy demands.  
**• Mature Economies** – Nations such as the US, UK, and Germany maintain high but stable emissions, reflecting slower economic expansion and ongoing energy transitions.  
**• Nuclear-Reliant Economies** – France stands out for its low and consistent emissions, achieved through long-term investment in nuclear energy and stable energy governance.