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Exploring the quarterly (quarter – on – quarter) real GDP growth of the G20 countries

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Prefatory Note (added at the Final Proofs stage): This paper was presented by the second author on the instructions of the first author to him at the One Day National Seminar held at the second author's institution on 25 October, 2024 on the theme titled "G20 – An Opportunity or Challenge: With Reference to India", as the first author could not personally visit Mussoorie to present this paper in the said Seminar owing to her certain exigencies and official engagements. All the three authors of this paper had a consensus on the presentation of this paper in the aforesaid seminar.

Abstract
In the backdrop of the eighteenth G20 Summit held at the Bharat Mandapam in New Delhi on 09-10 September, 2023, we decided to have a look at the quarterly (quarter-on-quarter) real Gross Domestic Product (GDP) growth of the G20 countries up to the latest quarter ending on 30 June 2024, the most current data about which could become available to us. In this very first paper of a series of our papers on this topic, we present a visualization of the data of the quarterly GDP growth of the member countries of this group of countries, except Argentina and Russia, because the corresponding complete data for these two countries could not become available to us. For arriving at some interesting conclusions based on the visualization of this multivariate data we employ the tools of multiple violin plot, multiple diamond plot, Andrews plot, Chernoff faces and the heat map.

Keywords: Gross Domestic Product (GDP), G20, Andrews plot, Chernoff faces, Violin plot, Heat map.

JEL Classification: C02, C12, C19, C21, C25, C29, C31, C35, C39, C49, C58, C59, C60, C63, C65, C69, C80, C83, C87, C88.
2020 Mathematics Subject Classification 62J02, 62J05, 62J10, 62J99, 62P05, 62P20, 91B62, 91B74, 91B99, 91G70, 91G99.

1. Introduction

The Cologne summit of the G7 countries in June 1999 paved the way for the formation of the G20 organization for international economic cooperation, when the G20 was initially founded on 26 September, 1999 during the G7 Finance Ministers' meeting which efforts later culminated into the inaugural meeting in Berlin on 15-16 December, 1999 leading to the birth of the G20 [1]. The birth of the G20 at the beginning of the present millennium had its roots embedded in a series of debt crises

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that shook the foundations and the stability of the world economy badly during the 1990s like the Mexican peso crisis, the 1997 Asian financial crisis and the 1998 Russian financial crisis which events also led to the hitting of the economy of the United States in 1998 [1]. Historically speaking, the erstwhile Finance Minister of Canada – Paul Martin and his American counterpart Larry Summers, the then U.S. Treasury Secretary are credited with the formation of the G20 (the Group of Twenty) in 1999, whose primary focus was on the global economy governance [1]. Though the Asian financial crisis of the late 1990s which, according to the western economists was attributed to the faulty policy of governance standards of these countries, led to the establishment of the forum of the G20, which concentrated on evolving "the best economic policy practices from its wealthy members with strategically significant developing-state members" [2, p.1]. But after a decade the world economy was hit by another strong wave of economic crisis, called the "global financial crisis", this time the epicenter was located in the economy of the USA and Europe. Though not all the regions of the world were hit by this economic crisis wave with equal force, yet with the Lehman Brothers investment bank of the US becoming bankrupt on 15 September, 2008, the international impact of this financial crisis began to be felt the world over due to which the stock markets crashed in several countries and a number of leading "financial institutions in Europe, Asia, and elsewhere experienced severe liquidity problems" [2, p. 2]. Luckhurst [2, p. 2] most beautifully describes the then prevailing situation in the global economic context in the following words:

"Policymakers around the world suddenly found themselves in profoundly challenging and uncertain economic circumstances. The US-led international economy and the liberal economic beliefs upon which the international economy was founded were undermined and brought into question. The most popular models of financial risk management suddenly lost credibility, while economic growth predictions were radically lowered in countries substantially exposed to the international economy, which meant the majority."

Since then the G20 summits of state leaders have been regularly held at least once annually, the first meeting of which was held on 14-15 November, 2008 at Washington D.C. in the United States [3]. Besides this the finance and economic ministers and the central bank governors of these countries also hold ministerial level meetings on topics of multilateral interest like "finance, trade, agriculture, affordable and accessible healthcare, pharma, tech series, technology advancements, health, and energy" [3]. The Finance Track meetings of the finance ministers and central bank governors of the G20 countries deliberate upon the global economic and financial issues, examine the implementation and progress of the ongoing initiatives for the global economic stability and growth, suggest and evolve measures for further coordination among the members to ensure a uniform pattern of global development [3].

In the year 2024 the G20 Leaders' Summit will be held in the month of November 2024 (precisely during 18-19 November, 2024) at Rio de Janeiro, in which the leaders of the nineteen member countries will participate along with those of the African Union and the European Union [4]. The theme (motto) of the 2024 G20 summit under the presidency of Brazil is "*Building a Just World and a Sustainable Planet*" [5]. The three main priorities in the agenda of the 2024 G20 summit are as listed below [5]:

(i). Social inclusion and the fight against hunger;
(ii). Energy transition and sustainable development in its social, economic and environmental aspects;
(iii). Reform of the global governance institutions.

Last year the 2023 G20 Leaders' summit was held at New Delhi during 9-10 September, 2023 under the presidency of India under the theme "*Vasudhaiv Kutumbakam* (meaning that the whole world is one family) equivalently, *One Earth, One Family, One Future*" [6,7].

If we look at the combined GDP of the G20 members, they "represent around 87% of the global GDP, 62% of the world´s population, and over 75% of global trade" [8]. Our aim to write this series of research papers on the G20 economy initially originated from a sincere suggestion to the second and third authors from the side of the first author, when she learnt some months back that in near future a one day national seminar was going to be held on this topic in the second author's institution. It was in the backdrop of this motivation provided to the second and third authors by the first author that we decided to write a series of research papers on the GDP of the G20 member countries, a topic which was suggested by the first author to the other two authors of this paper. Moving ahead in this proposed direction, it was planned among the authors of this paper that we shall use the latest available GDP growth data periodically released by the Organization for Economic

Co-operation and Development. Thus in this paper and in the forthcoming series of our papers on this topic we analyze the G20 GDP quarterly growth rate on a quarter to quarter basis, the latest data about which was released at Paris on 12 September, 2024 [9]. The methodology of compilation of this data [9] is discussed in detail in [10], which we find it instructive to refer to an interested reader.

This paper is in continuation of our previous studies [11-21]. In this first paper of our proposed series of forth coming research papers on the analysis of the economic parameters of the G20 member countries, we only present an overview of a visualization of this multivariate data based on the quarterly (quarter – on – quarter) real GDP growth rate [9] of these countries using the methods of multiple violin plot, multiple diamond plot, Andrews plots, Chernoff faces and the heat map. Accordingly the very simple outline of the paper includes a description of the secondary data meant for our analysis in this paper in section 2, followed by a detailed visualization of this data in section 3 utilizing the tools just mentioned and a brief concluding section 4 closes the paper.

1.1 Abbreviations used in the paper:

For the sake of the discussion of our ideas in this paper we find it convenient to use the following abbreviations.

GDP: Gross Domestic Product OECD: The Organization for Economic Co-operation and Development

2. Data for the study

We reproduce in Table 1 below the secondary data regarding the quarterly real GDP growth of the G20 countries. This data shows the percentage change in the real GDP of the G20 countries based on their GDP in the previous quarter and it is a seasonally adjusted data. The latest data on this issue, which could become available to us, is presented below and we most gratefully acknowledge the website https://www.oecd.org/content/dam/oecd/en/data/insights/statistical-releases/2024/9/g20-gdp-growth-Q2-2024.pdf of the OECD [9] from where we have drawn the entire data presented in Table 1 infra for our investigations of this paper. We do mention that the aforementioned website is the original source of the entire secondary data reproduced by us in Table 1 and we gratefully attribute that website as the original source of the data of Table 1 [9].

Since the GDP growth rate of Argentina for the period 2024Q2 (i.e., the second quarter of the year 2024) is not available, and further because reliable estimates of the GDP growth rates of the Russian federation are not separately available and the corresponding figures of Russia are included in the consolidated GDP growth of the G20 group of countries as shown in the first row of Table 1, therefore, we decided to exclude the GDP growth rates of Argentina and the Russian Federation from our analysis in section 3 onwards of this paper for ensuring the accuracy of results. Further we mention that we considered only the GDP growth rates of the European Union as shown in the antepenultimate row of Table 1 below and we dropped the GDP growth rates for the Euro area and the OECD area of the European Union as shown in the last two rows of Table 1 because these values are already included in the GDP growth rates of the European Union as already depicted in the third last row of Table 1.

Table 1: Quarterly (quarter-on-quarter) real GDP growth

Percentage change on the previous quarter, seasonally adjusted data.

Country	2022Q2	2022Q3	2022Q4	2023Q1	2023Q2	2023Q3	2023Q4	2024Q1	2024Q2
G20	0.0	1.5	0.5	1.0	0.8	0.8	0.7	0.8	0.7
Argentina	1.7	-0.1	-2.3	1.1	-2.4	2.3	-2.5	-2.6	…
Australia	0.9	0.1	0.7	0.5	0.5	0.3	0.2	0.2	0.2
Brazil	1.2	1.0	0.4	1.2	0.7	0.1	0.2	1.0	1.4
Canada	0.9	0.5	-0.2	0.8	0.2	-0.1	0.0	0.4	0.5
China	-2.1	4.0	0.8	1.8	0.8	1.5	1.2	1.5	0.7
France	0.4	0.5	0.1	0.0	0.7	0.1	0.4	0.3	0.2
Germany	0.0	0.6	-0.5	0.1	-0.2	0.2	-0.4	0.2	-0.1
India	0.8	1.9	1.2	2.3	2.4	1.8	2.0	1.7	1.3
Indonesia	1.2	1.1	1.3	1.2	1.3	1.3	1.3	1.2	1.2

Italy	1.4	0.4	-0.1	0.4	-0.1	0.3	0.1	0.3	0.2
Japan	1.1	-0.3	0.4	1.3	0.7	-1.1	0.1	-0.6	0.7
Korea	0.8	0.4	-0.5	0.4	0.6	0.8	0.5	1.3	-0.2
Mexico	1.0	0.9	0.9	0.6	1.0	0.7	-0.1	0.1	0.2
Russian Federation									
Saudi Arabia	1.2	1.2	1.5	-1.5	0.0	-2.3	-0.6	1.4	1.4
South Africa	-0.9	1.9	-1.4	0.6	0.7	-0.4	0.3	0.0	0.4
Türkiye	1.4	0.5	1.1	0.1	4.0	0.2	1.2	1.4	0.1
United Kingdom	0.1	-0.1	0.1	0.2	0.0	-0.1	-0.3	0.7	0.6
United States	-0.1	0.7	0.6	0.6	0.5	1.2	0.8	0.4	0.7
European Union	0.8	0.5	-0.2	0.1	0.1	0.2	0.1	0.3	0.2
of which: Euro area	0.9	0.5	-0.1	0.0	0.1	0.0	0.1	0.3	0.2
OECD area	0.5	0.5	0.3	0.4	0.5	0.4	0.4	0.4	0.5

…: not available

Note: The Russian Federation is included in the G20 estimates, but it is not shown separately. From Q4 2021, GDP figures for Russia are not included, as reliable estimates are not available, and the G20 totals are reweighted accordingly.

Source: OECD (2024) Quarterly National Accounts (Database)

Source: https://www.oecd.org/content/dam/oecd/en/data/insights/statistical-releases/2024/9/g20-gdp-growth-Q2-2024.pdf [9, Table 1, p. 2 of 4].

Table 2: The portion of the data of Table 1 investigated by us in this paper.

Country	2022Q2	2022Q3	2022Q4	2023Q1	2023Q2	2023Q3	2023Q4	2024Q1	2024Q2
1. G20	0.0	1.5	0.5	1.0	0.8	0.8	0.7	0.8	0.7
2. Australia	0.9	0.1	0.7	0.5	0.5	0.3	0.2	0.2	0.2
3. Brazil	1.2	1.0	0.4	1.2	0.7	0.1	0.2	1.0	1.4
4. Canada	0.9	0.5	-0.2	0.8	0.2	-0.1	0.0	0.4	0.5
5. China	-2.1	4.0	0.8	1.8	0.8	1.5	1.2	1.5	0.7
6. France	0.4	0.5	0.1	0.0	0.7	0.1	0.4	0.3	0.2
7. Germany	0.0	0.6	-0.5	0.1	-0.2	0.2	-0.4	0.2	-0.1
8. India	0.8	1.9	1.2	2.3	2.4	1.8	2.0	1.7	1.3
9. Indonesia	1.2	1.1	1.3	1.2	1.3	1.3	1.3	1.2	1.2
10. Italy	1.4	0.4	-0.1	0.4	-0.1	0.3	0.1	0.3	0.2
11. Japan	1.1	-0.3	0.4	1.3	0.7	-1.1	0.1	-0.6	0.7
12. Korea	0.8	0.4	-0.5	0.4	0.6	0.8	0.5	1.3	-0.2
13. Mexico	1.0	0.9	0.9	0.6	1.0	0.7	-0.1	0.1	0.2
14. Saudi Arabia	1.2	1.2	1.5	-1.5	0.0	-2.3	-0.6	1.4	1.4
15. South Africa	-0.9	1.9	-1.4	0.6	0.7	-0.4	0.3	0.0	0.4
16. Türkiye	1.4	0.5	1.1	0.1	4.0	0.2	1.2	1.4	0.1
17. United Kingdom	0.1	-0.1	0.1	0.2	0.0	-0.1	-0.3	0.7	0.6
18. United States	-0.1	0.7	0.6	0.6	0.5	1.2	0.8	0.4	0.7
19. European	0.8	0.5	-0.2	0.1	0.1	0.2	0.1	0.3	0.2

Union									

Source: [9, Table 1, p. 2 of 4].

The methodology adopted by the OECD for the compilation of the G20 Quarterly Economic Growth data of Table 1 is discussed in detail in [10] and we accordingly refer the interested reader to this reference for a better and deeper understanding of the methodology of compilation of the data of Table 1 above by the OECD, an issue on which we restrain ourselves to discuss here for reasons of brevity.

3. Visualizing the GDP data of Table 2

In this section we briefly point out to the readers only some of the striking features of the dataset of Table 2 using different techniques as stated earlier in section 1. For general reference works concerning multivariate analysis and graphical visualization of multivariate data we refer the interested readers to the sources [22-25].

3.1 A multiple violin plot view

For an introduction to the violin plots we refer the readers to [26-28]. We first concentrate on looking at some distinguishing features of the data of Table 2. First of all we consider the violin plots of the GDPs of the last nine quarters of the G20 countries which are shown in Fig. 1. Basically a violin plot is drawn by combining the box-and-whisker plot and a nonparametric density estimator. For computing the density traces of the nine quarter subsamples 2022Q2, 2022Q3, …, 2024Q2 of Table 2, we chose the interval width as 60% of the range covered on the y-axis by the GDP data values of that particular quarter using the cosine weighting function for smoothing the data. We can at once observe from Fig. 1 that the pattern of GDPs of the G20 countries during the past nine consecutive quarters has remained practically the same as is shown by the similarity of their density traces. The red colored plus (+) sign in the box-and whisker plots of Fig. 1 shows the mean GDP of the G20 countries during the particular quarter in question. We can see that the variation in the pattern of the sample means of the GDP of the G20 countries remains almost uniform throughout the last nine quarter periods of study. This fact is supported by Table 3, which shows the sample means and the sample standard deviations along with their 95% confidence intervals of the GDP of these countries, from where we see that the sample mean of the GDP of the G20 countries varies from a minimum of 0.289474 in 2023Q3 to a maximum of 0.910526 in 2022Q3. Further the larger lengths of the violin plots corresponding to the quarters 2022Q3, 2023Q1, 2023Q2 and 2023Q3 correspond to the higher values of the ranges of the GDP values corresponding to these quarters, as is shown by the highlighted red colored values of the ranges of 4.3, 3.8, 4.2 and 4.1 in Table 4. We also remark that in Table 4 the values of the standardized skewness and the standardized kurtosis (shown in red color) of the GDP of these countries corresponding to the quarters 2022Q2, 2022Q3, 2023Q1 (standardized kurtosis only), 2023Q2 and 2023Q3 (standardized kurtosis only) lie beyond the range of ±2, which characterizes significant departures from normality, and we will not be in a position to apply many statistical procedures to these sample values, which assume that these values are drawn from a normal distribution, like, for example , we mention that the 95% confidence intervals for the means and standard deviations of the nine variables of Table 2, shown in Table 3 are calculated on the assumption that the samples of these nine variables (quarters) came from populations which can be modeled by a normal distribution. ***Though the confidence intervals for the sample means of Table 3 are quiet sturdy and not very much influenced by the violation of the assumptions of normality, but the confidence intervals of the standard deviations shown in Table 2 are extremely sensitive to departures from normality and may altogether be inaccurate, unless we normalize the values corresponding to these five variables 2022Q2, 2022Q3, 2023Q1, 2023Q2 and 2023Q3 by using suitable transformations.***

Another interesting feature of the multiple violin diagram of Fig. 1 is that the reader will note that in the box-and-whisker plots corresponding to the variables 2022Q2, 2022Q3, 2023Q2 and 2023Q3 there are clearly visible square box like signs, some with a plus sign inside them (particularly those corresponding to the variables 2022Q3 and 2023Q2). ***These correspond to the presence of outside points or far outside points (lying respectively at distances more than 1.5 times and 3.0 times the interquartile range), and may well be outliers, to be detected and tested by a separate procedure (for details, see [12]), which we are, at present, not inclined to discuss here.*** To support these observations of ours we separately draw the box-and-whisker plots of the four

variables 2022Q2, 2022Q3, 2023Q2 and 2023Q3 in Figs. 2(a) -2(d). Fig. 2(a) shows that the value of the GDP of China at -2.1 in the quarter 2022Q2 is an outside point. Interestingly in the very next quarter the GDP of China at 4.0 is again a far outside point as shown in Fig. 2(b), which shows that ***China has extremely surprisingly recovered the growth of its own GDP from the lowest in the previous quarter to the greatest in the very next quarter during this period.*** The value of the GDP of India at 2.4 is an outside point and that of Türkiye at 4.0 is a far outside point in the quarter 2023Q2 as can be seen from Fig. 2(c). Similarly, in the quarter 2023Q3, the GDP of Saudi Arabia at -2.3 is an outside point as depicted in Fig. 2(d).

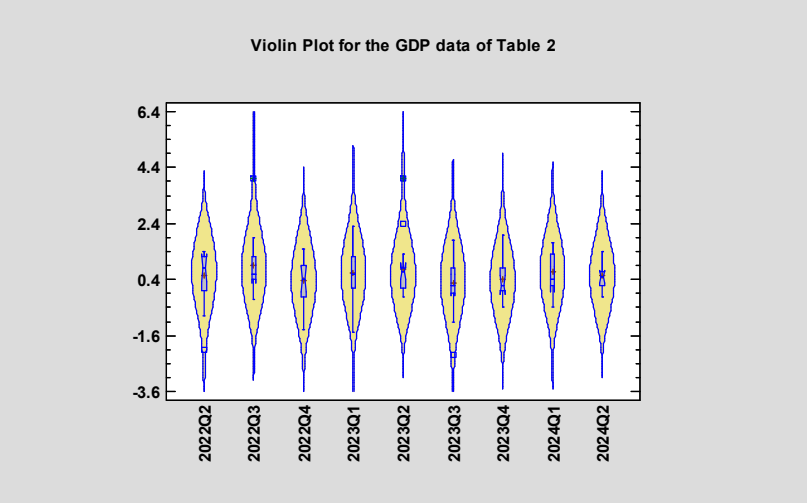

Fig. 1: Violin plots for the dataset of Table 2.

Table 3: Sample means and sample standard deviations of the quarterly GDP of the G 20 countries with their 95% confidence intervals.

95.0% confidence intervals of the GDP of the G 20 countries

	Mean	*Stnd. error*	*Lower limit*	*Upper limit*
2022Q2	0.531579	0.202478	0.106188	0.95697
2022Q3	0.910526	0.219368	0.449649	1.3714
2022Q4	0.352632	0.168128	-0.000593836	0.705857
2023Q1	0.615789	0.183415	0.230448	1.00113
2023Q2	0.773684	0.22476	0.30148	1.24589
2023Q3	0.289474	0.214925	-0.162068	0.741015
2023Q4	0.405263	0.151112	0.0877888	0.722738
2024Q1	0.663158	0.143109	0.362497	0.963819
2024Q2	0.547368	0.112746	0.310498	0.784239

	Sigma	*Lower limit*	*Upper limit*
2022Q2	0.88258	0.666889	1.30518
2022Q3	0.956205	0.72252	1.41406
2022Q4	0.732855	0.553754	1.08376
2023Q1	0.799488	0.604103	1.1823
2023Q2	0.979706	0.740279	1.44881
2023Q3	0.936836	0.707885	1.38541
2023Q4	0.65868	0.497707	0.974072
2024Q1	0.623797	0.471349	0.922486
2024Q2	0.491447	0.371344	0.726764

Table 4: Summary statistics of the quarterly GDP of the G20 countries.

Summary Statistics of the quarterly GDP of the G20 countries

	2022Q2	*2022Q3*	*2022Q4*	*2023Q1*	*2023Q2*	*2023Q3*
Count	19	19	19	19	19	19
Average	0.531579	0.910526	0.352632	0.615789	0.773684	0.289474
Standard deviation	0.88258	0.956205	0.732855	0.799488	0.979706	0.936836
Coeff. of variation	166.03%	105.017%	207.824%	129.831%	126.629%	323.634%
Minimum	-2.1	-0.3	-1.4	-1.5	-0.2	-2.3
Maximum	1.4	4.0	1.5	2.3	4.0	1.8
Range	3.5	4.3	2.9	3.8	4.2	4.1
Stnd. skewness	-3.07666	3.50609	-0.950306	-0.646513	4.11061	-1.76916
Stnd. kurtosis	3.01805	4.83588	0.230546	2.04651	5.6619	2.03925

	2023Q4	*2024Q1*	*2024Q2*
Count	19	19	19
Average	0.405263	0.663158	0.547368
Standard deviation	0.65868	0.623797	0.491447
Coeff. of variation	162.531%	94.0646%	89.7836%
Minimum	-0.6	-0.6	-0.2
Maximum	2.0	1.7	1.4
Range	2.6	2.3	1.6
Stnd. skewness	1.42118	0.0410135	0.900362
Stnd. kurtosis	0.39722	-0.675652	-0.619539

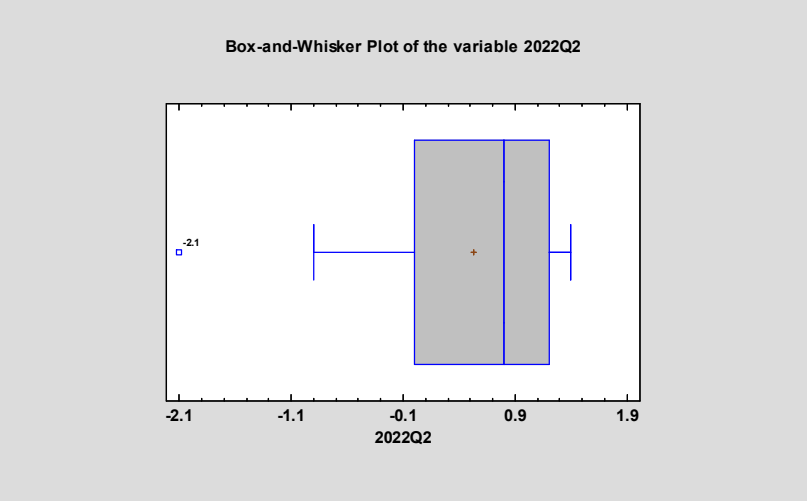

Fig. 2 (a): Box-and-whisker plot of the variable 2022Q2 showing the value of -2.1 (China) as an outside point.

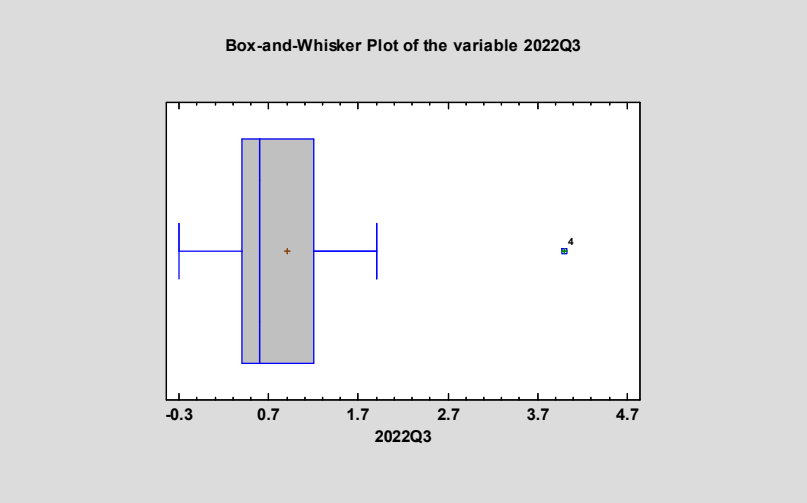

Fig. 2 (b): Box-and-whisker plot of the variable 2022Q3 showing the value of 4.0 (China) as a far outside point.

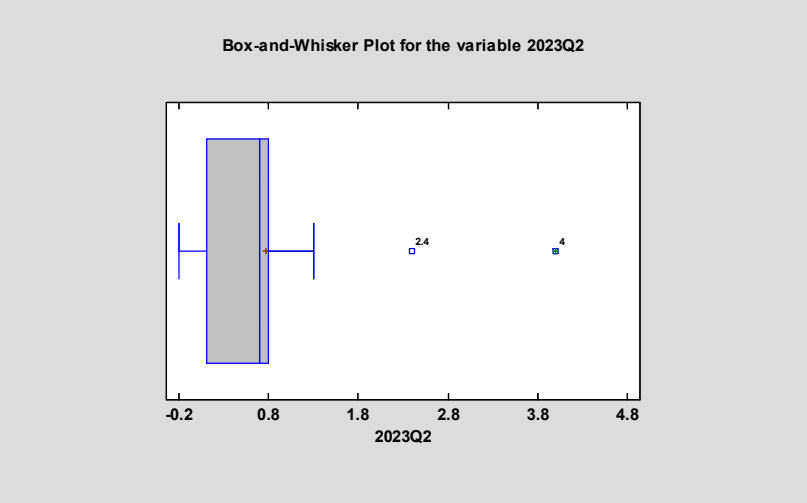

Fig. 2 (c): Box-and-whisker plot of the variable 2023Q2 showing the values of 2.4 (India) as an outside point and 4.0 (Türkiye) as a far outside point.

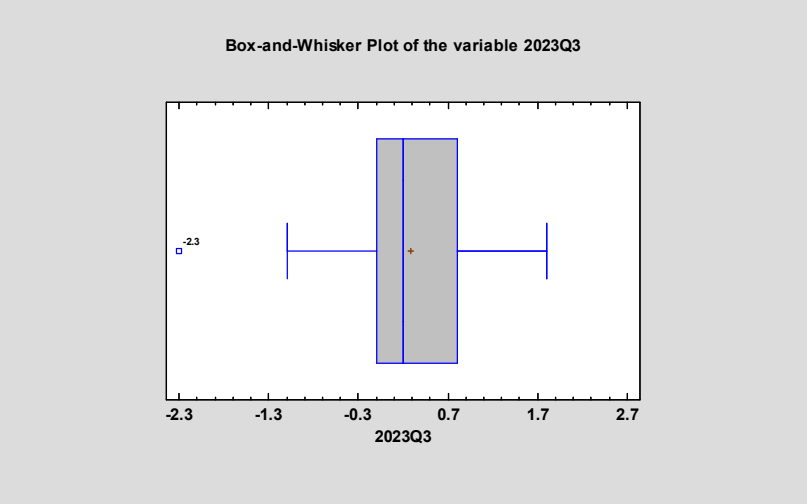

Fig. 2 (d): Box-and-whisker plot of the variable 2023Q2 showing the values of -2.3 (Saudi Arabia) as an outside point.

3.2 A multiple diamond plot view

For a quick introduction to the concept of diamond plots we can refer to [29, 30]. We draw a multiple diamond plot for the quarterly GDP values of the G20 countries in Fig. 3(a), which presents a comparative view of the GDP values of the G20 countries among the nine quarters of interest. In each plot the sample values are shown with a green colored shaded diamond, which extends from the lower confidence limit of the sample mean to its upper confidence limit. The variation in the limits of the variables 2022Q2, 2022Q3, 2023Q2 and 2023Q3 is easily observable from this plot. This confirms the findings of the outside points and far outside points in the previous subsection. For a detailed view of the diamond plot, we present the diamond plot of the latest quarter 2024Q2 in Fig. 3(b).

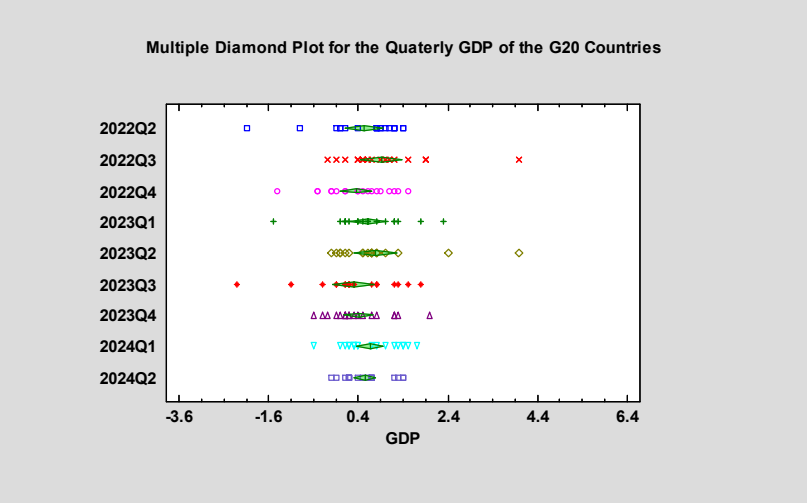

Fig. 3(a): A multiple diamond plot for the quarterly GDP of the G20 countries.

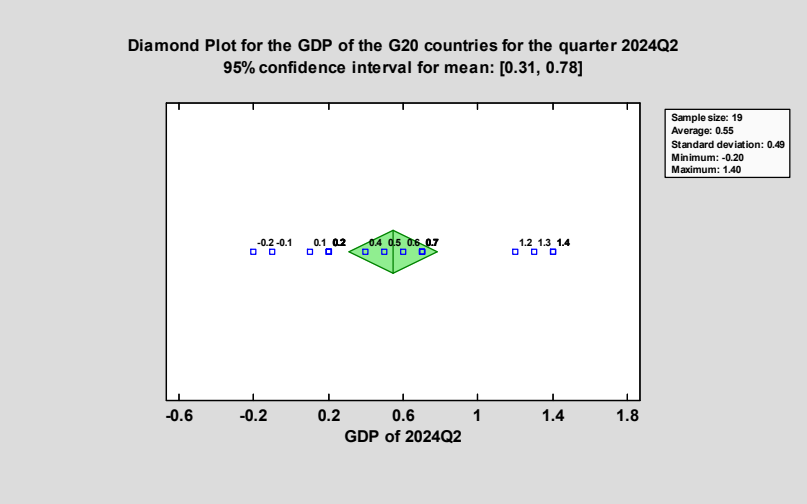

Fig. 3(b): Diamond plot for the GDP of 2024Q2.

3.3 An Andrews plot view

The basic introduction about Andrews plots and their usage can be seen from [31, 32]. Figs. 4(a)-4(c) present the Andrews plots for the quarterly GDP of the G20 countries, where the member countries are grouped in the alphabetical order of their names. The Andrews plots are important tools for the detection of similarities and differences between the cases in question. In Fig. 4(a) the sample values are standardized by the minimum and maximum method, where each variable value is scaled by subtracting it from its minimum value and then dividing it by the range. From Fig.

4(a) ***we observe that the maximum sinusoidal variation in the GDP values is shown by India***. The curves for the GDP of some other countries are also identified in this diagram. Similarly we draw the Andrews plot for the data of Table 2 in Fig. 4(b) using the mean and sigma standardization method in Fig. 4(b) and the same plot is redrawn by us in Fig. 4(c) without using any standardization method. In all these figures we identify the curves representing the GDP of India, China and Saudi Arabia for illustrative purposes only. It may be inferred from these Andrews plots that the pattern of the GDP of many countries is greatly clustered together.

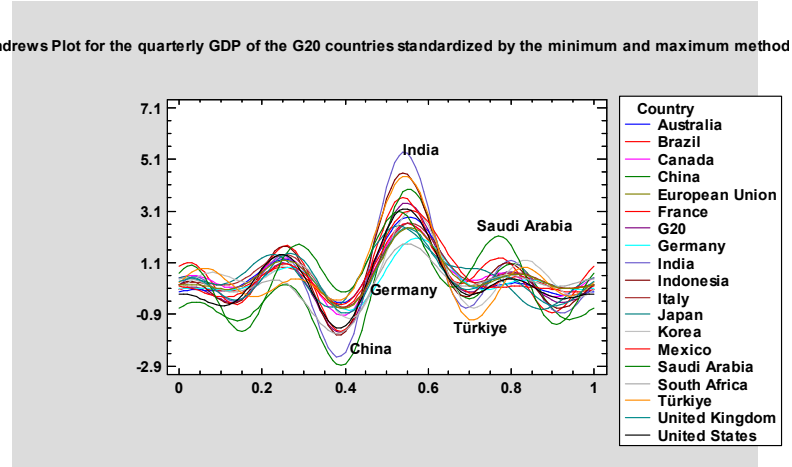

Fig. 4(a): Andrews plot for the quarterly GDP of the G20 countries standardized by the minimum and maximum method.

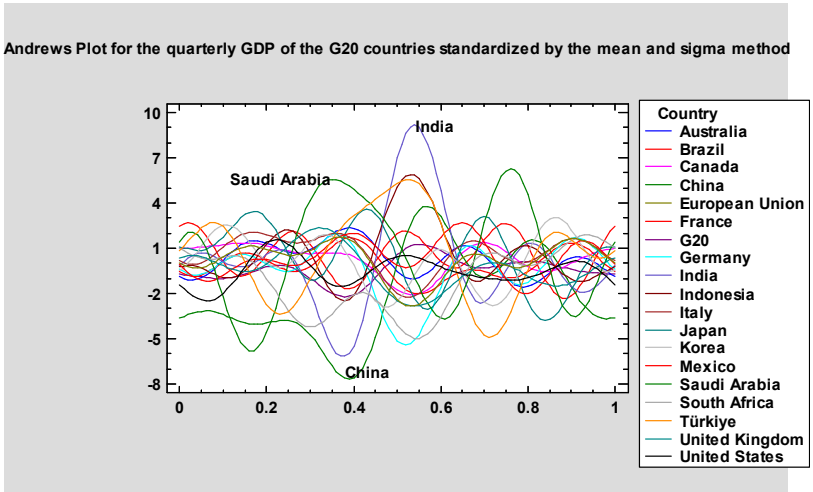

Fig. 4(b): Andrews plot for the quarterly GDP of the G20 countries standardized by the mean and sigma method.

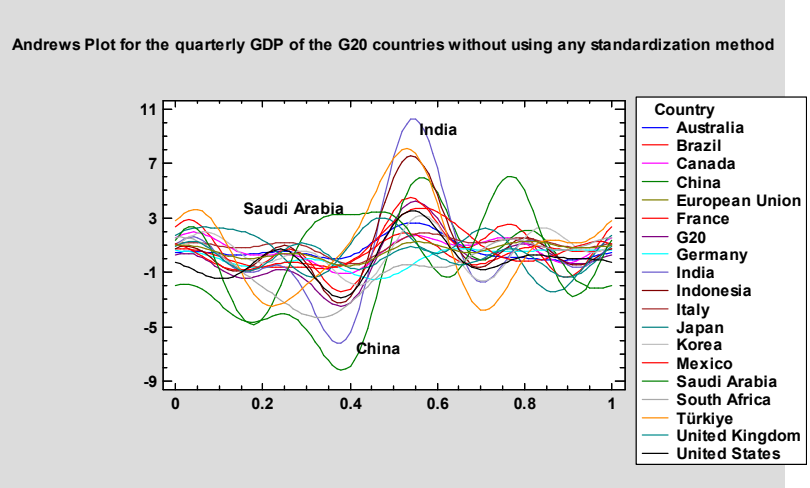

Fig. 4(c): Andrews plot for the quarterly GDP of the G20 countries without using any standardization method.

3.4 Chernoff faces plot view

In this subsection we draw Chernoff faces (see, [33, 34]) for the dataset of Table 2. The data variables used by us to draw Fig. 5(a) are described in Table 5 and the key glyphs for the interpretation of Fig. 5(a) are shown in Fig. 5(b). ***We can at once see from Fig. 5(a) that the largest face in the figure corresponds to the row number 8 of Table 2, which represents India. The eccentricity of the upper face for the case number 8 (India) is the greatest, which signifies the fact that for the variable 2023Q1, the maximum value of the sample corresponds to this case number 8 (India), which at once stands verified from a look of Table 2 which shows that the highest GDP growth rate during the quarter 2023Q1 is that of India at 2.3 amongst all the G20 member countries. Another notable feature of the case number 8 is that it has the greatest curvature of the mouth, which highlights the fact that again during the quarter 2024Q1 India (row 8 of Table 2) had the highest GDP growth rate of 1.7 as compared to the other members of the group G20. The vertical size of the faces characterizing the variable 2022Q4 is comparable in the case numbers 8,9, 14 and 16, which signifies the fact that during the quarter 2022Q4 the GDP growth rates of these countries as shown in Table 2 above – India (row 8), Indonesia (row 9), Saudi Arabia (row 14) and Türkiye (row 16) were almost nearly the same at 1.2, 1.3, 1.5 and 1.1. Further from Fig. 5(a) we also see that for the case number 15 the size of the face is the smallest – which highlights the important fact that during the quarter 2022Q4, South Africa (row 15 of Table 2) had the lowest GDP growth rate of -1.4! Another notable feature of Fig. 5(a) is that the width of mouth in the case number 12 is practically zero, which corresponds to the fact that in the latest quarter 2024Q2, Korea (row 12 of Table 2) had the minimum GDP growth rate of -0.2!*** In this manner we can draw a number of meaningful conclusions about the sample of Table 2 from viewing the Fig. 5(a) minutely. Here lies the beauty of the technique of Chernoff faces while looking at a multivariate sample, because many features of the entire sample, which at the first sight may otherwise go unnoticed can be highlighted by this procedure.

Table 5: Description of the data variables for the interpretation of Fig. 5(a).

Chernoff Faces
Data variables:
Radius to corner of face: 2022Q2
Angle of corner from horizontal: 2022Q3
Vertical size of face: 2022Q4
Eccentricity of upper face: 2023Q1
Eccentricity of lower face: 2023Q2
Length of nose: 2023Q3
Vertical position of mouth: 2023Q4
Curvature of mouth: 2024Q1
Width of mouth: 2024Q2

Number of complete cases: 19

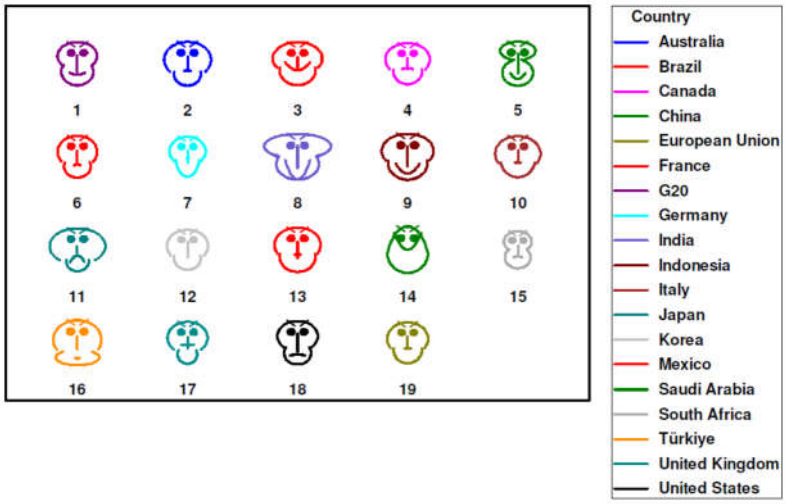

Fig. 5(a): Chernoff faces for the quarterly GDP of the G20 countries.

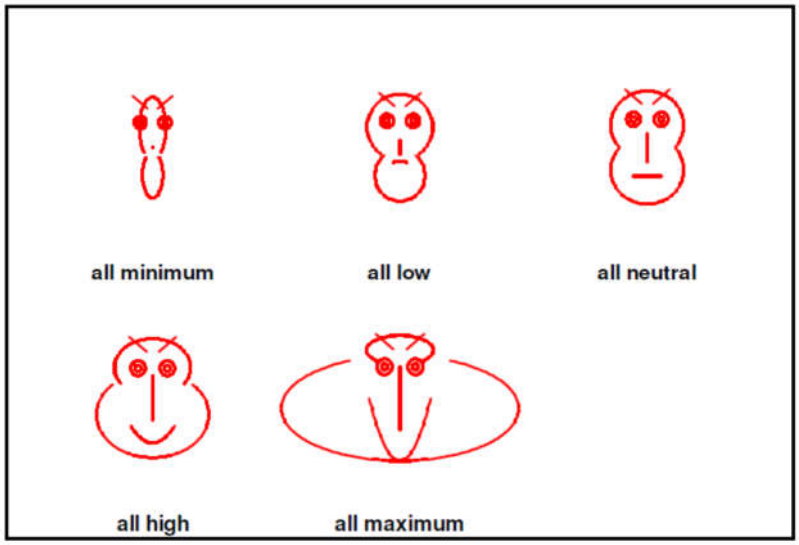

Fig. 5(b): Key glyphs for Fig. 5(a).

3.5 A heat map view

We now look at the sample of Table 2 with the help of a heat map (see, for instance, [35, 36]) shown below in Fig. 6. The heat map of Fig. 6 shows a comparative view of the real GDP growth rates among the nine quarters against the members of the G20 group. The color scheme of the plot involves a color scheme ranging from a dark blue color for the lowest values to a dark red color for the greatest values. It is very obvious from Fig. 6 that ***the dark blue color appears at two places – first for China in the quarter 2022Q2 signifying its lowest GDP growth rate of -2.1 amongst all the member countries, secondly, for Saudi Arabia in the quarter 2023Q3 which also indicates the smallest GDP growth rate of -2.3 amongst these countries in the said quarter. Talking about India, in the quarters 2022Q3, 2023Q1, 2023Q2 and 2023Q4 which periods correspond approximately to the second highest GDP growth rates during the periods under consideration, correspond to the entries in row 8 (India) 1.9, 2.3, 2.4 and 2.0 which are the four highest GDP growth rates recorded by India during the period of study as evidenced from Table 2 above. The two maximum GDP growth rates attained by any member country of G20 are of 4.0 (see Table 2) recorded by two dark yellow color bands in Fig. 6, which respectively correspond to the achievements of China in the quarter 2022Q3 and Türkiye during the period 2023Q2***. Similarly, many other inferences regarding the dataset of Table 2 can be drawn by us from the heat map of Fig. 6.

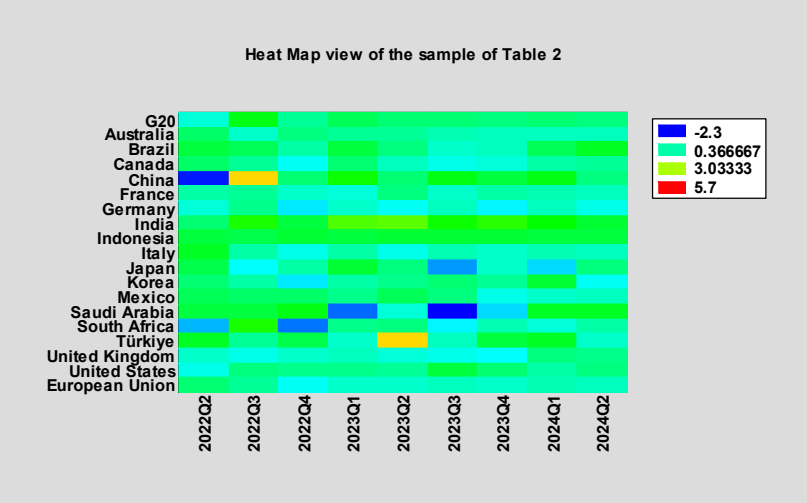

Fig. 6: A heat map view of the sample of Table 2.

4 Conclusions

In this paper we carried out a visualization of the quarterly (quarter – on – quarter) GDP real growth rate of the member countries of the G20 during the quarters 2022Q2 to 2024Q2 using the techniques of the multiple violin plot, the multiple diamond plot, the Andrews plot, the Chernoff faces and the heat map and drew some interesting conclusions about the sample of Table 2. We also drew some box-and-whisker plots of the dataset of Table 2 to arrive at some more specific conclusions. Our forthcoming papers of this series would focus on formulating some mathematical models for the dataset of Table 2.

Acknowledgments

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https://www.oecd.org/content/dam/oecd/en/data/insights/statistical-releases/2024/9/g20-gdp-growth-Q2-2024.pdf
and its Administrators from where they have gratefully drawn the entire data of Table 1 (hence that of Table 2), above, which is studied and analyzed by them in this paper. The authors also record their appreciation about the diligent efforts of the anonymous reviewers and the editors, whose many meaningful comments have helped the authors improve and enrich the contents of this paper.

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