HIGH SCHOOL EDITION
Journal of Student Research
Volume 13 Issue 1 (2024)

Relationship Between a Country's Economy and Gold Medals in Tokyo 2020 Summer Olympics and Beijing 2022 Winter Olympics

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ABSTRACT

My objective is to find how strong the correlation between economic factors of a country and the amount of gold medals won in the 2020 Summer and 2022 Winter Olympics. The economic factors of a country I used are Gross Domestic Product (GDP US dollars) and Gross Domestic Product per capita (GDP per capita US dollars). I used separate Pearson's Product Moment Correlation Coefficient (r) test to determine the correlation between these factors and the gold medal count in the Summer and Winter Olympics. There is a positive correlation between a country's GDP and the number of gold medals it earns in the 2020 Summer Olympics. However, there is not a positive correlation between a country's GDP and the number of gold medals it earns in the Winter Olympics. The $r^2 = 0.743$ for a country's GDP and the number of gold medals it earns in the 2020 Summer Olympics indicates other factors also contribute to gold medals probably including population, host country (prior, current, and future), and political system. My analysis suggests that GDP per capita seem to play a more significant role for the Winter Olympic than the Summer Olympics. It is possible that culture and geographic locations play critical roles for winning gold medal in the Winter Olympics owing to the more limited set up of games which are normally not available to many countries in the tropical or subtropical regions.

Introduction

The Olympic Games is a global, multi-sport athletics competition with over 200 countries participating in over 400 events between the Summer and Winter Olympic Games. Every four years, the International Olympic Committee hosts the Summer and Winter Olympics staggered, meaning that there's an Olympic event every two years. For example, the 2020 Summer Olympics was held in Tokyo, Japan and the 2022 Winter Olympics was held in Beijing, China. The different between the Summer and Winter Olympics is the competitions held. As such, the Summer Olympic Games include competitions like swimming, cycling, and gymnastics, and the Winter Olympic Games include competitions like figure skating, snowboarding, and ski jumping.

In the Olympic Games, not all countries win a medal and not all countries only win a single medal. Variables that may have an influence on a countries' Olympic performance could be its population size, economic rank, resources, the hosting country, and overall economic power (Andreff, W. 2001; Bernard and Busse 2004; Vagenas and Vlachokyriakou, 2012)

Previous studies suggest that population, income per capita, host country (prior, current, and future), and political system have a significant impact on a countries' Olympic performance (Johnson and Ali 2000; Bernard and Busse 2000; Grancay and Dudas 2018). Here I aim to test the number of Olympic medals to the gross domestic product (GDP) and the gross domestic product per capita (GDP per capita) for different countries. In addition, the 2020 Summer Olympics was postponed to 2021 because of COVID-19, which could have

an effect on the results, thus making this year a special circumstance on the nation's economy. I want to investigate whether there is a relationship between economic power and Olympic performance by different countries during this special circumstance.

Method

The lists of nations participating at the Pyeongchang and Tokyo 2020 Summer Olympic games and Beijing 2022 Winter Olympic games were obtained from (Beijing 2022; Tokyo 2020). The GDP and the GDP per capita data were acquired from The World Bank (2021; 2022).

First, I explored the GDP and the GDP per capita of twenty countries from the World Bank (2021; 2022). I then analyzed their relationship with the medal count of the Summer Olympics and Winter Olympics in four separate Pearson's Product Moment Correlation Coefficient (r) tests. For the 2020 Summer Olympics, I conducted two separate correlation tests with GDP (US dollars) and GDP per capita (US dollars) and did the same with the 2022 Winter Olympics. This allowed me to compare the results and differences between the Summer and Winter Olympics metal count and if the economics power of a country affects the gold medal count. To test the correlation between the GDP and the GDP per capita to the number of gold metals a country wins from the Olympics. I used scatter diagrams and the Pearson's Product Correlation Coefficient.

Furthermore, I explored the data and the correlation to create a scatter diagram to see if there is a correlation between the economic factors of a country and the number of metals earned. If a linear correlation cannot be obtained, Spearman's Rank Correlation Coefficient was calculated to determine if a linear relationship exits.

In addition, I used linear regression in order to predict the number of gold medals that can be earned in the future Summer and Winter Olympics. I analyzed the linear regression equation of the Pearson's Product Correlation Coefficient tests and gathered data on a country's estimated GDP and GDP per capita. By using this estimated data, I predicted the number of medals a county will earn in future Olympic events if there is a correlation found in the Pearson's Product Correlation Coefficient tests.

Because I aimed to compare the results of the 2020 Summer Olympics and 2022 Winter Olympics, I choose countries that participated in both the 2020 Summer Olympics and 2022 Winter Olympics. Consequently, the total number of participating countries of both games was 90. Using a random list generator website (https://www.random.org/lists/), I randomly choose twenty countries to study for my correlation tests.

Results

After obtaining my data for twenty countries, I decided that my first statistical analysis of my exploration would be to conduct four separate Pearson's Product Moment Correlation Coefficient analyses to test the correlation between the amount of gold medals a country earns and the country's economic power.

The reason for this is because I want to find the distributions of the GDP in billions of US dollars and GDP per capita for the twenty countries. Using this method, I wanted to use my TI-84 Plus CE graphing calculator in order to graph the spread of the data set. I will be using a scatter diagram; therefore, I can visually explore the spread of the data set. This visual will allow me to compare the GDP per capita and GDP of the twenty countries and determine the distribution between the many countries.

Table 1. Countries' GDP and GDP per capita in 2021 and gold medals earned in the 2020 Summer Olympics

Countries	GDP (billions, US dollars)	GDP per capita (US dollars)	Number of Gold Medals
Australia	1,542.66	59,934.10	17
Austria	477.08	53,267.90	1
Belarus	68.22	7,303.70	1
Belgium	599.88	51,767.80	3
Canada	1,990.76	52,051.40	7
China	17,734.06	12,556.30	38
Czech Republic	282.34	26,378.50	4
France	2,937.47	43,518.50	10
Germany	4,223.12	50,801.80	10
Great Britain	3,186.86	47,334.40	22
Hungary	182.28	18,772.70	6
Japan	4,937.42	39,285.20	27
Netherlands	1,018.01	58,061.00	10
New Zealand	249.99	48,801.70	7
Norway	482.44	89,202.80	4
Russian Olympic Committee (ROC)	1,775.80	12172.8	20
Slovenia	61.53	29200.8	3
Spain	1,425.28	30115.7	3
Sweden	627.44	60239	3
US	22,996.00	69287.5	39

Table 2. Countries' GDP and GDP per capita in 2022 and gold medals earned in the 2022 Winter Olympics

Countries	GDP (billions, US dollars)	GDP per capita (US dollars)	Number of Gold Medals
Australia	1,724.79	66,408	1
Austria	468.05	52,062	7
Belarus	79.7	8,570	0
Belgium	589.49	50,598	1
Canada	2,200.35	56,794	4
China	18,321.20	12,970	9
Czech Republic	295.62	28,095	1
France	2,778.09	42,330	5
Germany	4,031.15	48,398	12
Great Britain	3,198.47	47,318	1
Hungary	184.65	18,980	1
Japan	4,300.62	34,358	3
Netherlands	990.58	56,298	8
New Zealand	242.7	47,278	2
Norway	504.7	92,646	16

Russian Olympic Committee (ROC)	2,133.09	14,670	6
Slovenia	62.19	29,469	2
Spain	1,389.93	29,198	0
Sweden	603.92	56,361	8
US	25,035.16	75,180	8

The 2020 Summer Olympics was held in 2021 instead of 2020 because of the global pandemic COVID-19. Thus, I decided to use the GDP and the GDP per capita of 2021, rather than the GDP and GDP per capita of 2020 (Table 1).

Pearson's Product-Moment Correlation Coefficient

After gathering my data, I conducted a Pearson's Product Moment Correlation Coefficient (r). This allows me to determine the strength of the correlation between the number of gold medals earned in the Summer and Winter Olympics and a countries' economy.

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \Sigma(y_i - \bar{y})^2}}$$

x: the number of gold medals earned, *y:* the GDP (in US dollars) or the GDP per capita (in US dollars) of the countries, depending on the test. With the creation of Table 3, I can find each variable in my formula in order to calculate *r*. For Table 3, *x* represents the number of gold medals earned and *y* represents the GDP (in US dollars) of the 20 countries. This will help me find the correlation between the number of gold medals and the GDP (in US dollars) of countries in the 2020 Summer Olympics.

Table 3. r variables

GDP (in billions of US dollars)	Gold Medals					
x	y	$(x - \bar{x})$	$(y - \bar{y})$	$(x - \bar{x})(y - \bar{y})$	$(x - \bar{x})^2$	$(y - \bar{y})^2$
1,542.66	17	-1,797.27	5.25	-9435.678	3230186.642	27.5625
477.08	1	-2,862.85	-10.75	30775.659	8195921.574	115.5625
68.22	1	-3,271.71	-10.75	35170.904	10704099.41	115.5625
599.88	3	-2,740.05	-8.75	23975.455	7507884.963	76.5625
1,990.76	7	-1,349.17	-4.75	6408.567	1820265.086	22.5625
17,734.06	38	14,394.13	26.25	377845.86	207190920.9	689.0625
282.34	4	-3,057.59	-7.75	23696.338	9348868.838	60.0625
2,937.47	10	-402.46	-1.75	704.3085	161975.6614	3.0625
4,223.12	10	883.19	-1.75	-1545.579	780021.0433	3.0625
3,186.86	22	-153.07	10.25	-1568.988	23431.03718	105.0625

182.28	6	-3,157.65	-5.75	18156.499	9970766.153	33.0625
4,937.42	27	1,597.49	15.25	24361.692	2551967.91	232.5625
1,018.01	10	-2,321.92	-1.75	4063.3635	5391321.774	3.0625
249.99	7	-3,089.94	-4.75	14677.2245	9547741.563	22.5625
482.44	4	-2,857.49	-7.75	22145.563	8165260.53	60.0625
1,775.80	20	-1,564.13	8.25	-12904.089	2446508.913	68.0625
61.53	3	-3,278.40	-8.75	28686.0175	10747919.67	76.5625
1,425.28	3	-1,914.65	-8.75	16753.205	3665892.281	76.5625
627.44	3	-2,712.49	-8.75	23734.305	7357612.85	76.5625
22,996.00	39	19,656.07	27.25	535627.853	386361009.2	742.5625

Here are the totals from Table 3:

Σx	Σy	$\Sigma (x - \bar{x})(y - \bar{y})$	$\Sigma (x - \bar{x})^2$	$\Sigma (y - \bar{y})^2$
3262880.883	11.75	1161328.48	695169576	2609.75

For this formula, I did not need the sum of $(x - \bar{x})$ and $(y - \bar{y})$. Instead, I used these numbers to calculate the $(x - \bar{x})(y - \bar{y})$, as well as the additional formulas shown. Then I plugged these numbers into the Pearson's formula to calculate r.

$$r = \frac{1{,}161{,}328.48}{\sqrt{(695{,}169{,}576)(2{,}609.75)}}$$

$$r = 0.862204$$

or $r \approx 0.862$

Using my TI-84 Plus CE graphing calculator, I checked my work. I also used my TI-84 Plus CE graphing calculator to calculate the r^2 value on my scatter diagram in order to check if my value was correct as shown in Graph 1: GDP (in billions of US dollars) VS Gold Medals in the 2020 Summer Olympics.

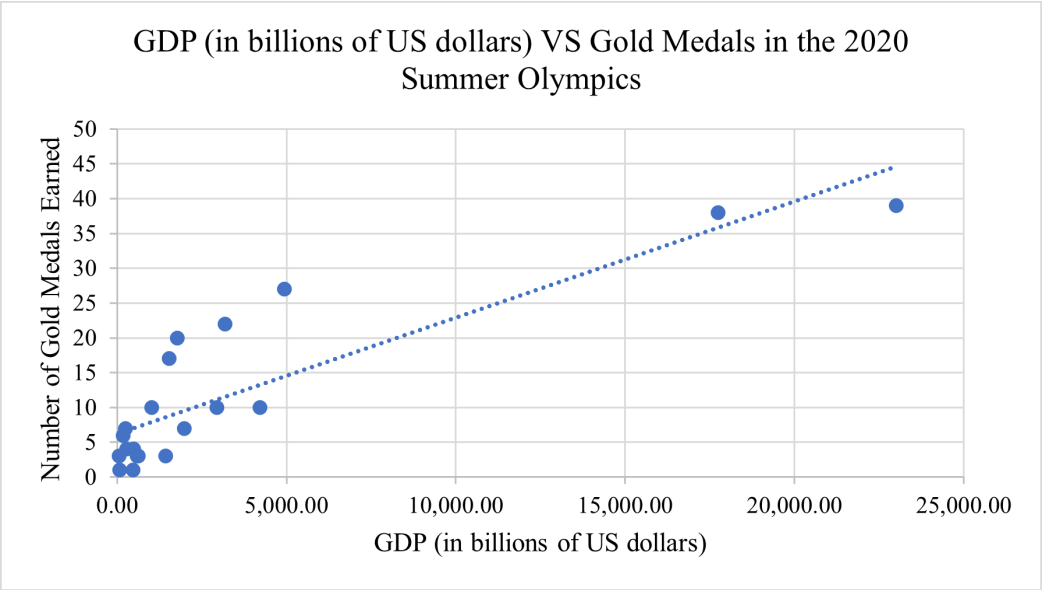

Figure 1. Relationship between GDP (in billions of US dollars) and Gold Medals of each country in the 2020 Summer Olympics.

$$r \approx 0.862,\ r^2 \approx 0.743$$

After using my TI-84 Plus CE graphing calculator to confirm that my *r* value is correct, I observed that there is a linear positive correlation between a countries' GDP (in billions of US dollars) and the gold medals earned in the 2020 Summer Olympics (r^2=0.743, Figure 1). Looking at this scatter plot, I realized that the majority of the randomly chosen countries had low GDP, especially in comparison to countries like the United States of America and China.

Using Excel, I determined the linear regression line to reflect on the result more. I repeated this process for the rest of my test.

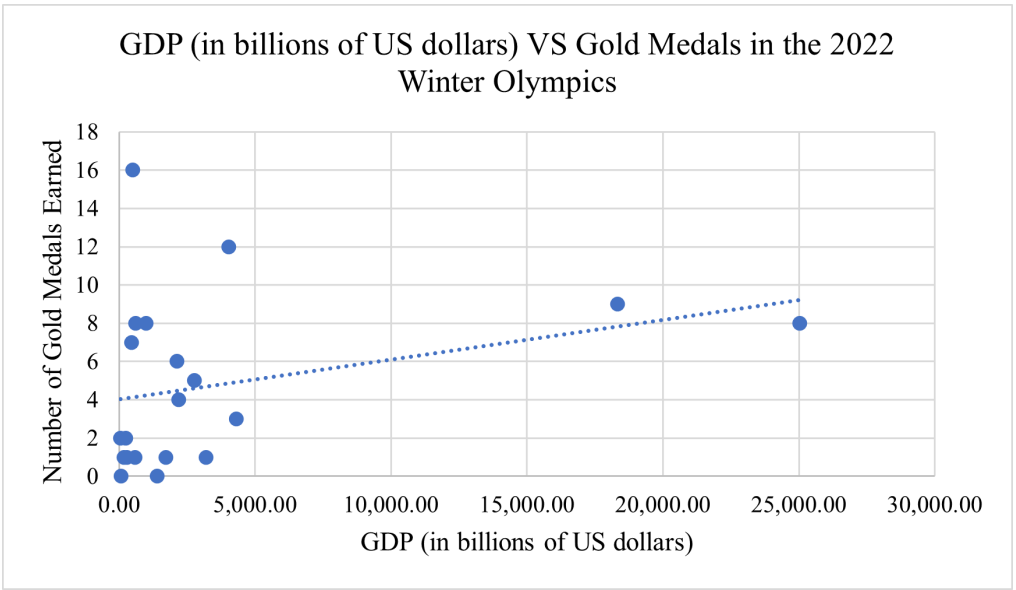

Figure 2. The relationship between GDP (in billions of US dollars) and Gold Medals in the 2022 Winter Olympics.

$$r \approx 0.303,\ r^2 \approx 0.092$$

As seen in Figure 2, there is a very weak positive correlation between a country's GDP and the number of gold medals earned in the 2022 Winter Olympics (r^2=0.092, Figure 2). After seeing the difference between Figure 1 and Figure 2, I was surprised to find that there is a significant difference between the Summer and Winter Olympic results.

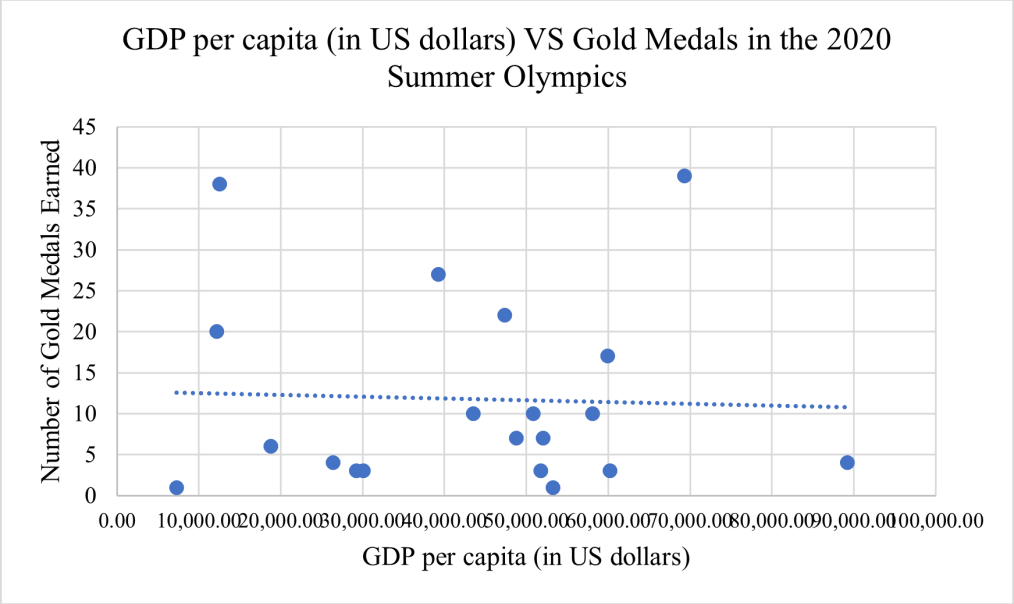

Figure 3. The relationship between GDP per capita (in US dollars) and Gold Medals in the 2020 Summer Olympics.

$$r \approx -0.0390,\ r^2 \approx 0.00152$$

As shown in Figure 3, there is a very weak negative correlation represented. This shows that there is a weak relationship between a countries' GDP per capita, which measures the value of output per person, and the amount of gold medals the country earns in the 2020 Summer Olympics.

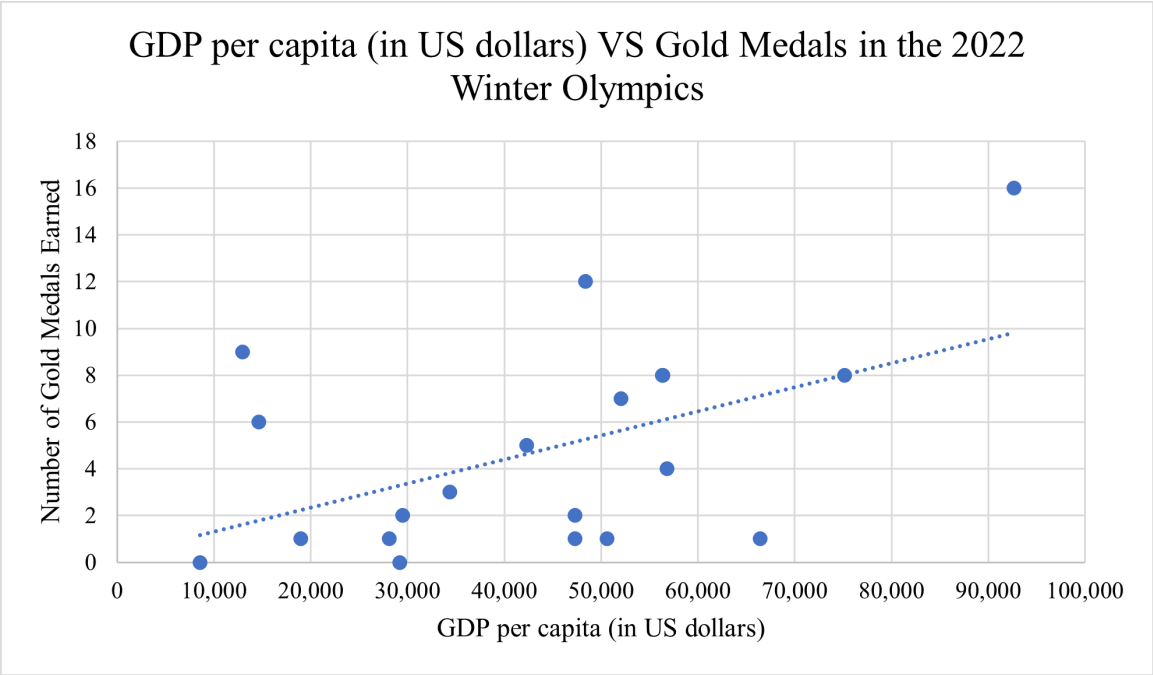

Figure 4. The relationship between GDP per capita (in US dollars) and Gold Medals in the 2022 Winter Olympics.

$$r \approx 0.506,\ r^2 \approx 0.256$$

From the spread of the data and r^2 value, we can see that there is a linear weak positive correlation between a country's GDP per capita (in US dollars) and the number of gold medals earned in the 2022 Winter Olympics (Figure 4). Though it is a slight difference, there is a difference between the correlation of a country's GDP per capita and number of gold medals in the 2020 Summer and 2022 Winter Olympics.

Linear Regression

After receiving the results from these bivariate tests, I decided to use Linear Regression to predict the future values of future Olympic games. Because the only linear correlation found was GDP (in billions of US dollars) VS Gold Medals in the 2020 Summer Olympics (Figure 1), I only applied the linear regression to this test. Attempting to predict future values with a very weak and weak correlation will lead to an unreliable equation and estimate, therefore I did not accept the very weak and weak correlation for Figures 2, 3, and 4.

$$Y = aX + b \text{ (Equation 1)}$$

For the linear regression as shown in Equation 1, Y represents the predicated number of total gold medal, or dependent variable, X represents GDP (in billions of US dollars), or independent variable, a represents the estimated slope, and b is the estimated intercept. During these tests to find the linear regression line of the previous Pearson's Product-Moment Correlation Coefficient test, Y will represent the number of predicted gold medals while X will be the predicted data gathered from research.

$Y = (M_y - bM_y)\ X + (\frac{SP}{SSx})$ (Equation 2)

To show my work, I broke down the linear regression equation as shown in Equation 2. I will let M_y represent the mean of *Y*, M_y represent the mean of *X*, *SP* represent the sum of products, and SS_x represent the sum of squares of *x*. Using the data I gathered before, I created Table 4 to determine each of these variables to find *a* and *b*. For Table 4, *x* will be the countries' GDP (in billions of US dollars) in 2021 and *y* will be the number of gold medals earned in the 2020 Summer Olympics.

Table 4. a and b variables

GDP (in billions of US dollars)	Gold Medals				
x	y	$(x - \bar{x})$	$(y - \bar{y})$	$(x - \bar{x})^2$	$(x - \bar{x})(y - \bar{y})$
1,542.66	17	-1,797.27	5.25	3230186.642	-9435.678
477.08	1	-2,862.85	-10.75	8195921.574	30775.659
68.22	1	-3,271.71	-10.75	10704099.41	35170.904
599.88	3	-2,740.05	-8.75	7507884.963	23975.455
1,990.76	7	-1,349.17	-4.75	1820265.086	6408.567
17,734.06	38	14,394.13	26.25	207190920.9	377845.86
282.34	4	-3,057.59	-7.75	9348868.838	23696.338
2,937.47	10	-402.46	-1.75	161975.6614	704.3085
4,223.12	10	883.19	-1.75	780021.0433	-1545.579
3,186.86	22	-153.07	10.25	23431.03718	-1568.988
182.28	6	-3,157.65	-5.75	9970766.153	18156.499
4,937.42	27	1,597.49	15.25	2551967.91	24361.692
1,018.01	10	-2,321.92	-1.75	5391321.774	4063.3635
249.99	7	-3,089.94	-4.75	9547741.563	14677.2245
482.44	4	-2,857.49	-7.75	8165260.53	22145.563
1,775.80	20	-1,564.13	8.25	2446508.913	-12904.089
61.53	3	-3,278.40	-8.75	10747919.67	28686.0175
1,425.28	3	-1,914.65	-8.75	3665892.281	16753.205
627.44	3	-2,712.49	-8.75	7357612.85	23734.305
22,996.00	39	19,656.07	27.25	386361009.2	535627.853

Here are the totals of Table 4:

$\bar{x}$	$\bar{y}$	$\sum (x - \bar{x})^2$	$\sum (x - \bar{x})(y - \bar{y})$
3339.93	11.75	695169576.006	1161328.48

For this equation, the sum of $(x - \bar{x})$ and $(y - \bar{y})$ are not needed.
First, I use these totals to find *b*, or $(\frac{SP}{SSx})$.

$$(\frac{1161328.48}{695169576.006}) = 0.00167057$$
$$b \approx 0.00167$$

Using this, I then found a using the previous stated equation of $M_y - bM_y$.

$$11.75 - (0.001670568621 \times 3339.93) = 6.170414404$$

$$a \approx 6.17$$

Going back and applying the original equation 1 of $Y = aX + b$, I found the linear regression line of Figure 1: GDP (in billions of US dollars) VS Gold Medals in the 2020 Summer Olympics.

$$Y = 0.00167X + 6.17 \text{ (Equation 3) or}$$

Number of Gold Medals = 0.00167 (GDP in billions of US dollars) + 6.17

Since the next Summer Olympics will be held in 2024, I gathered data on a country's predicted GDP in 2024 as shown in Table 5.

Table 5. Predicted GDP (in billions of US dollars) and Gold Medals in Summer Olympics of countries in 2024

Countries	Predicted GDP in 2024	Countries	Rounded Predicted Count of Gold Medals*
Australia	1,837.69	Australia	9
Austria	494.052	Austria	7
Belarus	95.06	Belarus	6
Belgium	619.313	Belgium	7
Canada	2,420.68	Canada	10
China	20,699.15	China	41
Czech Republic	337.756	Czech Republic	7
France	2,932.36	France	11
Germany	4,337.39	Germany	13
Great Britain	3,757.40	Great Britain	12
Hungary	211.679	Hungary	7
Japan	4,568.73	Japan	14
Netherlands	1,076.96	Netherlands	8
New Zealand	264.967	New Zealand	7
Norway	495.142	Norway	7
ROC	2,146.70	ROC	10
Slovenia	70.043	Slovenia	6

Spain	1,508.90	Spain	9
Sweden	693.15	Sweden	7
US	27,057.20	US	51

* The numbers were rounded using basic rule to find the predicted count of gold medals.

Thus, I predicted the number of gold medals countries will earn in the 2024 Summer Olympics (Table 5).

Reflecting from my data and results, I can assume that these predicted values are not entirely accurate because there was only a linear, moderate positive correlation between a country's GDP (in billions of US dollars) and the number of gold medals earned in the 2020 Summer Olympics. In addition, these charts and formulas show extrapolation as I am attempting to predict future data based on past data. Generally, extrapolation is less accurate than interpolation.

Discussion

To conclude, there is a positive correlation between a country's GDP and the number of gold medals it earns in the Summer Olympics. This is consistent with previous studies (Li et al. 2022; (Vagenas and Vlachokyriakou, 2012). However, I did not observe the relationship between total gold medals and income per capita based on the analysis of the relationship between a country's economy and the number of gold medals it earns in the Summer Olympics (Andreff, W. 2001; Bernard and Busse 2004). The $r^2 = 0.743$ for a country's GDP and the number of gold medals it earns in the 2020 Summer Olympics indicates other factors also contribute to gold medals probably including population, host country (prior, current, and future), and political system (Hoffmann et al. 2002).

However, there is not a positive correlation between a country's GDP and the number of gold medals it earns in the Winter Olympics. My analysis suggests that GDP per capita seem to play a more significant role for the Winter Olympic than the Summer Olympics. It is possible that culture and geographic locations play critical roles for winning gold medal in the Winter Olympics owing to the more limited set up of games which are normally not available to many countries in the tropical or subtropical regions. Take Norway as an example, despite having such a low GDP (in billions of US dollars), Norway has the most gold medals in the 2022 Winter Olympics. It is one of the world's northernmost countries and Norwegians are used to sports related to snow and ice.

There were some limitations to my data. When I was testing for both Summer and Winter Olympics, I had to choose countries that participated in both Olympics, thus reducing the countries that I could test on to 90. This meant that many countries were excluded from my random sampling for this test. This would not have been a problem if I did separate tests for each Olympic competition instead of comparing the difference between the Summer and Winter Olympics. Because of the amount of data for 90 countries, I decided to use random sampling and choose 20 countries for further analyses. For both the Summer and Winter Olympics test, I used the same 20 countries throughout the test in order to be able to compare the results and correlation between the tests.

In conclusion, there is a positive correlation between the number of gold medals a country earns in the Summer Olympics, which is not observed in the Winter Olympics.

Acknowledgments

I would like to thank my advisor for the valuable insight provided to me on this topic.

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