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Analyze the Relationship Between CO_2 Emissions and GDP from the Global Perspective

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ABSTRACT

Over the centuries, the effect of CO_2 emissions has attracted attention both at the national and international levels. The rapid economic growth in past years causes the increase of CO_2 emission, being an essential factor that increases global warming. However, what is the relationship between CO_2 emission and GDP growth in the long run? Is it true that the relationship is always positive? In this paper, CO_2 emission data and GDP data were collected from the World Bank database and analyzed the relationship between CO2 emission and GDP growth from a global perspective with a regression method. Finally, CO_2 has a negative relationship with GDP based on data recorded in the past 50 years.

Keywords: *CO2 emission, global warming, GDP growth.*

1. INTRODUCTION

The United States aims to regain its position as a climate change leader by setting an ambitious goal of achieving zero carbon emissions by 2050, while China puts itself on the path of zero carbon emissions by 2060. Nevertheless, both are pursuing economic growth at the same time. Economic growth indicates an increase in real GDP, and people are likely to see a cost to the environment. As consumption increases, the corresponding opportunity cost is that the reserve of non-renewable resources decreases. Air pollution serves as a good example; when people increase their consumption of fossil fuels, the opportunity cost means poor air quality. So, people always pay the price of polluting the environment to increase GDP. In 2021, US President Joe Biden took his first action in office to rejoin the Paris climate agreement. This agreement has united the nations to encounter the environmental issue to change the temperature far below 2.0C. Under this agreement, all nations made their emission-reduction plans. Li et al. [1] found out that the carbon intensity had decreased to 0.129 in China by analysing the data from 2005 to 2015. Specifically, he concluded that the Chinese government allocated different carbon reduction goals to each province; the western part of China would release more carbon dioxide than the eastern part of China because the underdeveloped area has a faster economy growing. They unveiled the fact that a high-speed economy growing unavoidably causes CO_2 booms. Specifically, Al-Mullaly et al. [2] declared that Malaysia's developing country has a GDP increased by pollution. Hosseini et al. [3] also argued that Iran is the seventh-highest CO_2 emission country because of its abundant fossil resources, and this resource mainly supports its GDP. However, recent studies found evidence to show that Iran currently encounters overwhelming environmental issues.

Moreover, CO_2 is the product of fossil fuel, and America's oil and gas industry support about 8 percent of GDP. Accordingly, people intuitively believe that the relationship between GDP and economic growth is positive, and whether or not the goal of the Paris Climate Agreement can be achieved remains controversial. However, Aden [4] showed that 20 countries had reduced CO_2 emissions while the remaining GDP grew. These nations included both developed and developing countries, showing that the lower the CO_2 emission, the higher GDP growth. Despite this, Marjanovic et al. [5] found that 27% of 181 countries would have income growth while reducing emissions in the future. Therefore, the region serves as a confounding variable to determine if the result of the relationship will be changed based on different regions.

There are so many studies about finding the relationship between CO_2 and GDP. However, from the global perspective, the research of finding the long-term relationship between CO_2 emission and GDP among the

main economic regions lacked. Therefore, this paper will determine the relationship between CO_2 emission and GDP from a global perspective based on the data collected from four regions (North America, Latin America, European Union, and East Asia) and the world from 1960 to 2016. The structure of the rest of this paper is as follows: the second section is Data Description, the third section is Empirical Results and Discussion, and the final section is Conclusion.

2. DATA DESCRIPTION

2.1. Introduction of Data

The data used to be analyzed by using four existing data from the world bank, which are CO_2 emission metric tons per capita, GDP per capita growth on an annual basis, CO_2 emission (kt), GDP (in US dollar). The data has included the years from 1960 to 2016 with 268 variables. The variables contain a series name, series code, year, time code, and 264 different regions globally. Specifically, the region contains countries, continents, and organizations such as European Union amongst regions. In this study, European Union, North America, East Asia, and Latin America serve as confounding regions to reflect the relationship between CO_2 emission and GDP growth. The result on a regional basis will be determined if it is consistent with the result worldwide.

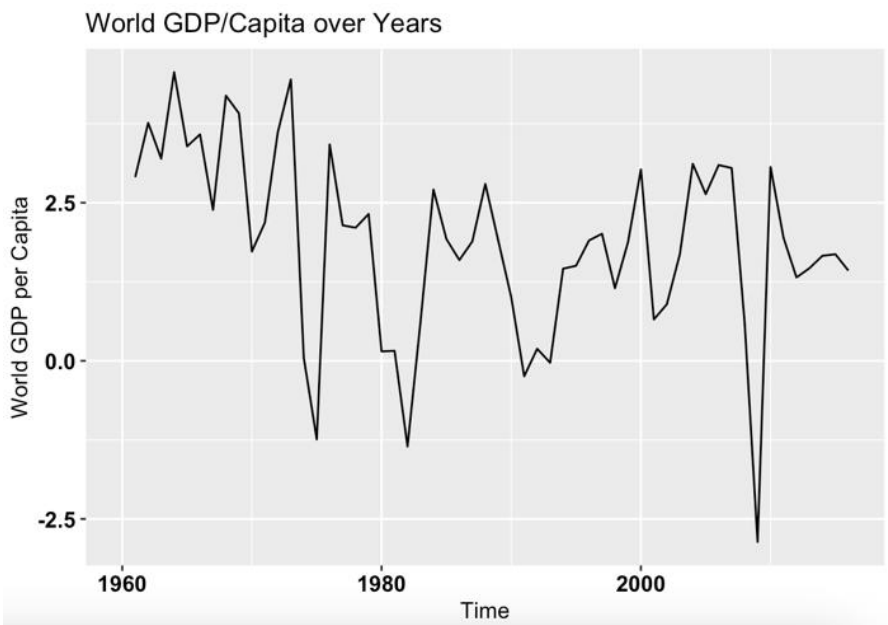
2.2. Data Description

2.2.1. Data Description about GDP per capita over years

Table 1. (The Percentage about the Positive and Negative GDP Growth from 1960 to 2016)

Negative growth of Global GDP per capita over years	Positive growth of Global GDP per capita over years
0.08928571	0.91071429

Table 1 indicated the situation of global GDP growth. From 1960 to 2016, 8.9% of years showed that the GDP growth globally was negative. However, the global GDP exhibits a positive value in most years, showing the global GDP maintained growing in most years.



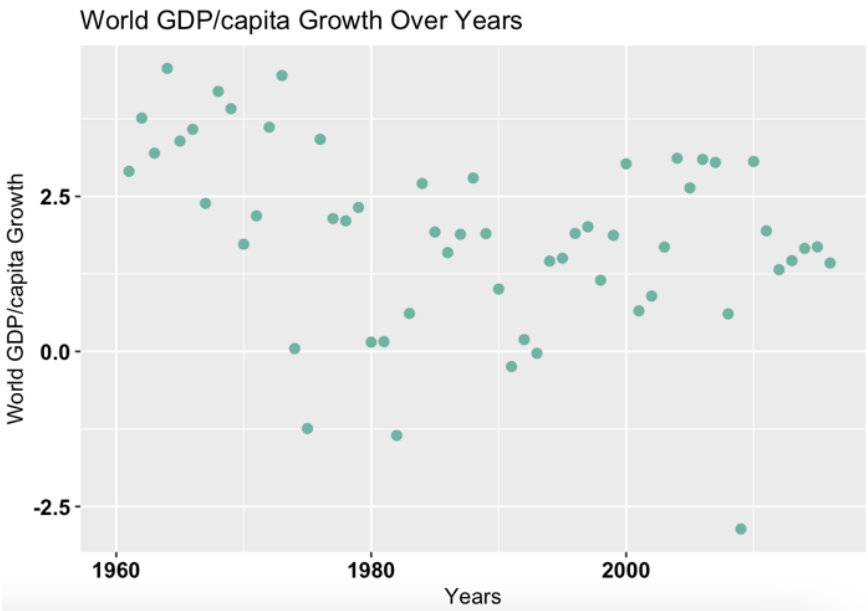


Figure 1. World GDP per capita over years

Figure 1 is the scatter plot that each dot represents the value of two numeric variables: the years and world GDP/capita growth. Before 1980, the world GDP per capita growth was relatively higher than the following years, but it was varied and not stable. Specifically, the GDP per capita growth in this period exceed 2.5 in certain years but dropped dramatically. Between 1980 and 2000, the GDP per capita growth was lower than the GDP per capita growth before 1980. Yet, the GDP per capita growth in this period was relatively stable. After 2000, the GDP per capita growth was stable in the most year, except the year around 2008. In 2008, the financial crisis occurred, causing the GDP to drop dramatically, and the GDP per capita growth of that year was the lowest since 1960. Unfortunately, the GDP per capita growth was -2.5 in 2008, and it was about 0.625 in the previous year, showing that people had a really tough life in 2008.

2.2.2. Data Description about CO2 emission per capita over years

Table 2. The information of CO_2 emission per capita from 1960 to 2016.

Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
2.993	3.910	4.233	4.127	4.428	4.754

In table 2, the data represents the overall situation of CO_2 emission throughout the world from 1960 to 2016. As table 2 shown, the maximum CO_2 emission per capita in this period had reached 4.754. By comparing the minimum CO_2 emission per capita, the range is 1.761. In the meantime, the Inter quartile range (IQR) is 0.518, and the mean is a little bit lower than the median by 0.106, showing that the data is left skew. The main reason behind this is the minimum drove the mean lower as the minimum is too small in the entire data. High-emission data are relatively concentrated on the right, accounting for a higher proportion than low-emission data.

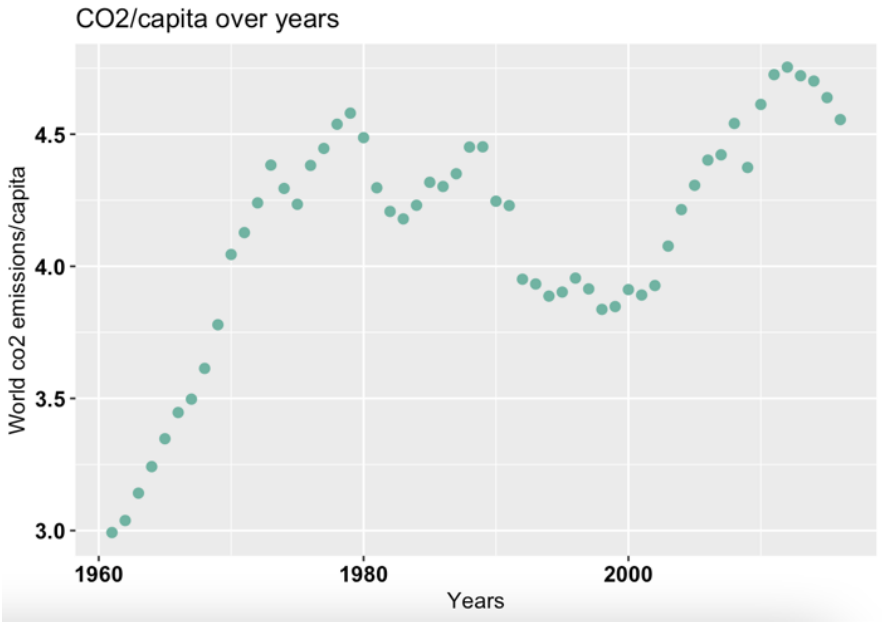


Figure 2. CO_2 Emission per capita over years

Based on Figure 2, the relationship between years and World CO_2 emission per capita is positive overall. Specifically, people released more CO_2 as each year passed between 1960 and 1980 since the slope is steeper in this period. In figure II, the scatter plot about the GDP per capita growth in the same period exhibits high GDP per capita growth, greater than 2.5. It inductively supported that the growth rate of world CO_2 emission per capita has a positive relationship with GDP growth per capita. Continuously, the world CO_2 emission per capita was declining approximately from 1980 to 2000. In the same period shown in figure II, the world GDP growth per capita was relatively lower than before 1980, showing lower GDP growth per capita the lower world CO_2 emission per capita in this period. Since 2000, the world CO_2 emission per capita increased while the GDP per capita growth remained the same in the big picture. It might because other factors drove the world's CO_2 worse at the same time. By comparing Figure II and Figure IV, causality exists. Thus, the paper will analyze the causality relationship between CO_2 emission and GDP based on the regression method.

2.2.3. World CO_2 emission in terms of GDP

In this section, figure 5 shows the World's CO_2 emission in terms of world GDP. In contrast, the remaining figures unveil the relationship about the world GDP in each region, where European Union, East Asia, North America, and Latin America.

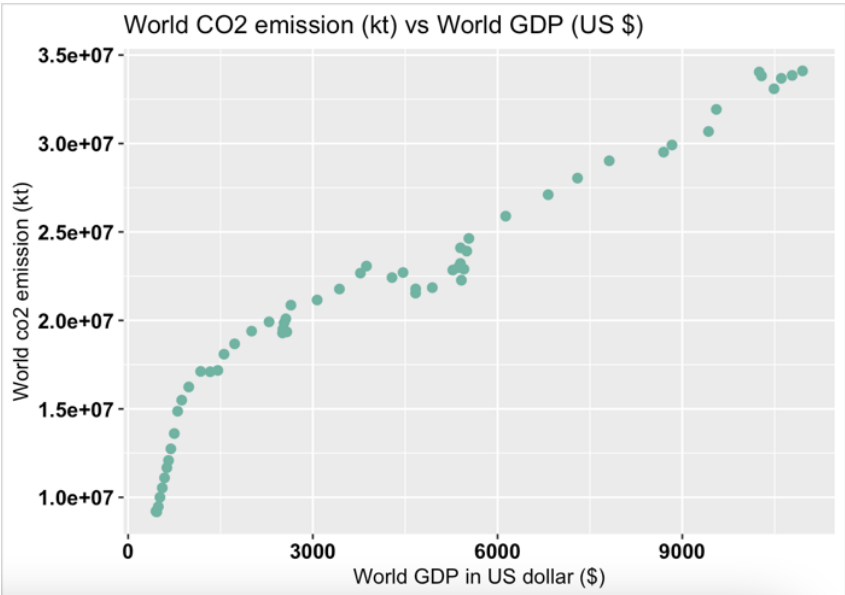


Figure 3. World CO_2 emission (kt) vs. World GDP (US dollars)

Now, the data is extracted from world CO_2 emission (kt) and world GDP (in US trillion dollar), shown in Figure 3. In this figure, the relationship between CO_2 emission and world GDP is positive from 1960 to 2016. Note that the world GDP in 1980 is 2532.8091 trillion US dollars, and the world GDP in 1986 is 3069 trillion US dollars. Also, note that the GDP remains growing over the years. Thus, before 3000 trillion US dollars (or the year 1980), one unit increased in World GDP cause more CO_2 emission by comparing with the year after 1980. Therefore, this figure is consistent with figure 2. One potential reason for the strict positive relationship between world CO_2 emission and world GDP in the period between 1960 and 1980 is that people were not aware of the relationship between CO_2 and GDP and did not care about the environment as much as we do today.

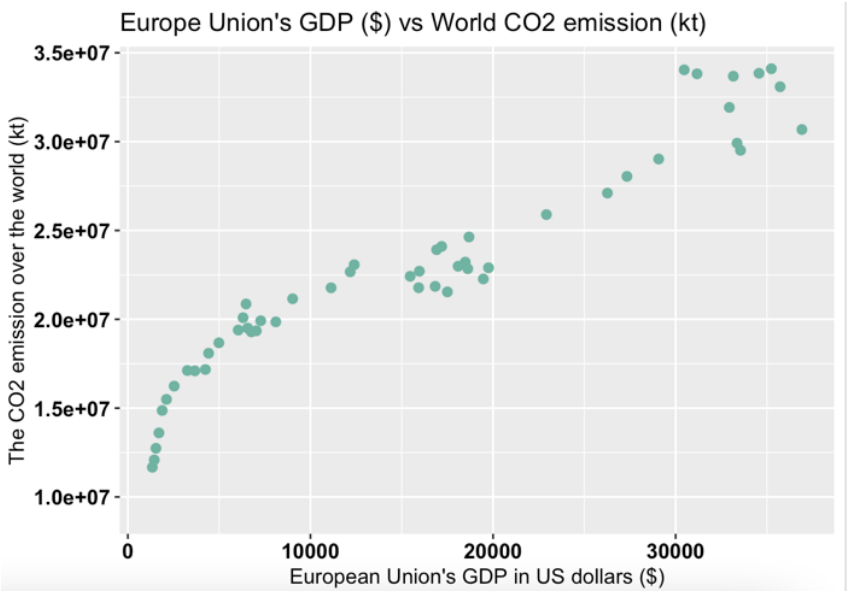


Figure 4. Europe Union's GDP($) VS World CO_2 Emission (Kt)

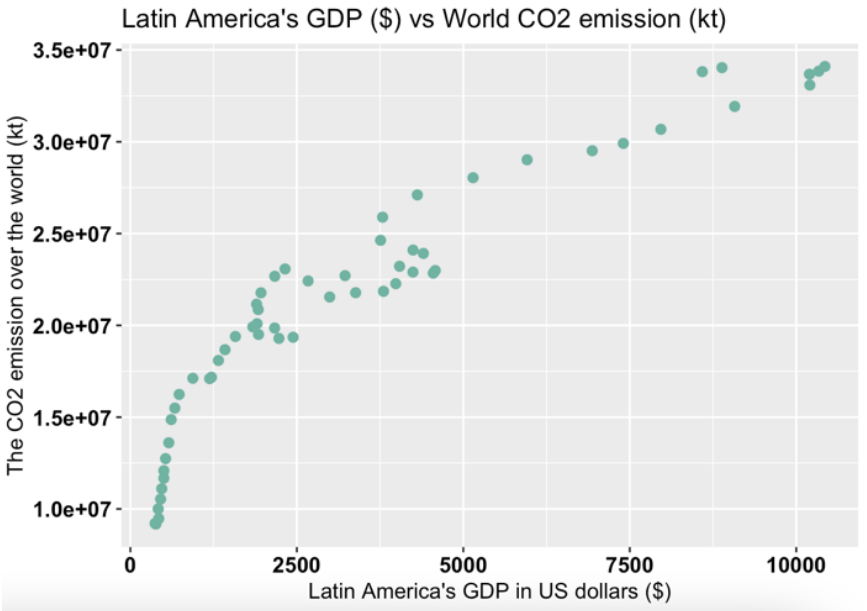


Figure 5. Latin America's GDP ($) VS World CO_2 emission (kt)

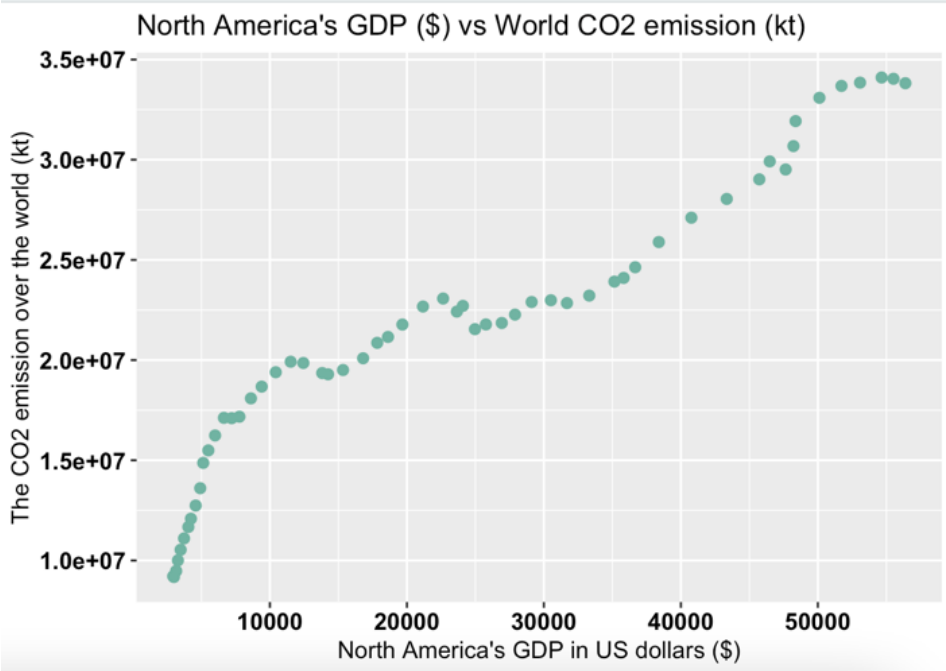


Figure 6. North America's GDP ($) VS World CO_2 emission (kt)

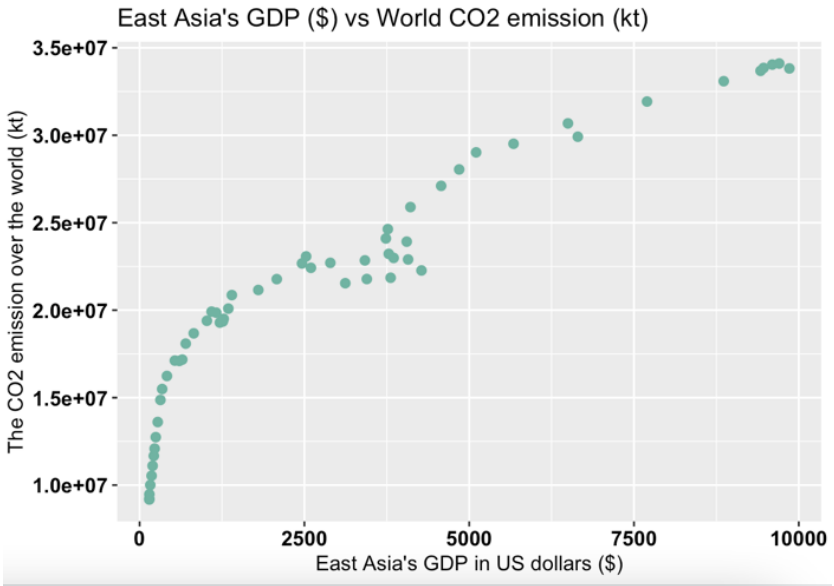


Figure 7. East Asia's GDP ($) VS World CO_2 Emission (kt)

The figures (4 to 7) show the situation of CO_2 emission in terms of regional GDP. All these figures show a positive relation, showing that the region is not a confounding variable that will affect the result based on a different region. Regarding the case of each region, more information will be presented in the following section.

3. EMPIRICAL RESULTS AND DISCUSSION

3.1. Analysis of the Relationship Between GDP and CO_2 Emission

First, the regression analysis is applied to find out the relationship between GDP and CO_2 emission. The analysis result is shown in both graph and table below.

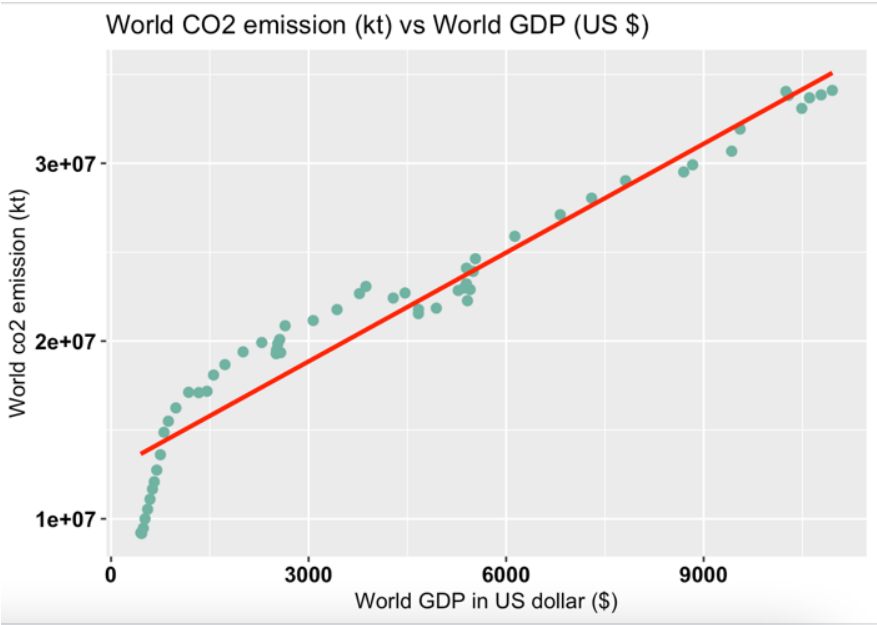


Figure 8. World CO_2 emission (kt) vs. World GDP (US dollars)

Table 3. World CO_2 emission (kt) vs. World GDP (US dollars)

Residuals:				
Min	1Q	Median	3Q	Max
-4502078	-961122	343595	1499327	2736284
Coefficients:				
	Estimate	Std. Error	t value	Pr(>|t|)
(intercept)	1.273e+07	4.119e+05	30.91	<2e-16
world_gdp	2.041e+03	7.636e+01	26.73	<2e-16
Residual Stand error: 1895000 on 55 degrees of freedom				
Multiple R-squared: 0.9285, Adjusted R-squared: 0.9772				
F-statistic 714.4 on 1 and 55 DF, p-value 2.2e-16				

Based on figure 8 and its corresponding table (table 3), 2041 units increased in world CO_2 emission as one unit increase in world GDP, showing a positive relationship between world CO_2 emission and world GDP. In the table, the adjusted R-squared of 0.9772 suggests that most data point indeed lie at the regression line, and the p-value is small enough to reject the null hypothesis in which there is no relationship between world CO_2 emission and world GDP. In the figure, the relationship between GDP below approximately 1500 trillion US dollar and world CO_2 emission has a steeper slope than the one with GDP above 1500 trillion US dollar. It shows that the environmental issue in terms of GDP is getting better as more people are aware of environmental protection.

3.2. Analysis of the Relationship Between World CO_2 Emission with Each Regional GDP

The following analysis will determine if the region is a confounding variable. The four regions are European Union, Latin America, North America, and East Asia.

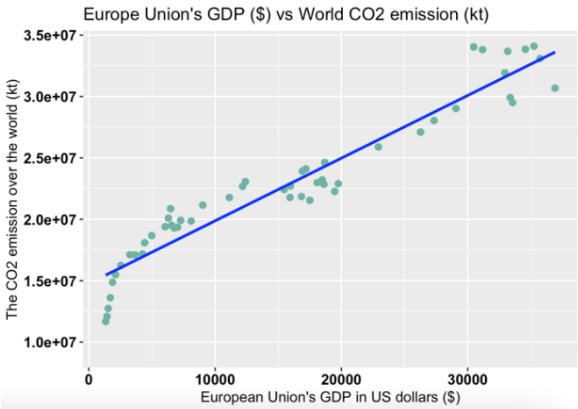


Figure 9. Europe Union's GDP($) VS World CO_2 Emission (Kt)

Table 4. Europe Union's GDP($) VS World CO_2 Emission (Kt)

Residuals:				
Min	1Q	Median	3Q	Max
-3779336	-1096567	240153	1351119	3713025
Coefficients:				
	Estimate	Std. Error	t value	Pr(>|t|)
(intercept)	1.477e+07	4.197e+05	35.18	<2e-16
EU_gdp	5.107e+02	2.160e+01	23.64	<2e-16
Residual Stand error: 1752000 on 49 degrees of freedom				
Multiple R-squared: 0.9194, Adjusted R-squared: 0.9177				
F-statistic: 558.9 on 1 and 49 DF, p-value: < 2.2e-16				

In figure 9 and table 4, the regression line in the figure also exhibits a positive relationship between CO_2 emission and GDP in European Union, showing that one unit increased in GDP of the European Union causes a 510.7 increased in world CO_2 emission. Similarly, the R-squared here is 0.9177, which is big enough to show the observation is likely to lie on the regression line. Also, the p-value is small enough to reject the null hypothesis, which is the change of GDP in the European Union will not affect the world CO_2 emission. As shown in figure V, figure VI has a steeper slope in the earlier time that the GDP is below about 5000 trillion US dollar. Dogan et al. [6] points out the importance of energy efficiency since it is a good way to largely reduce CO_2 emissions while maintaining GDP growth. They suggest that European governments must share awareness of energy efficiency with the public. Despite this, they also suggest that installing renewable resources such as solar panels and wind tribunes are necessary.

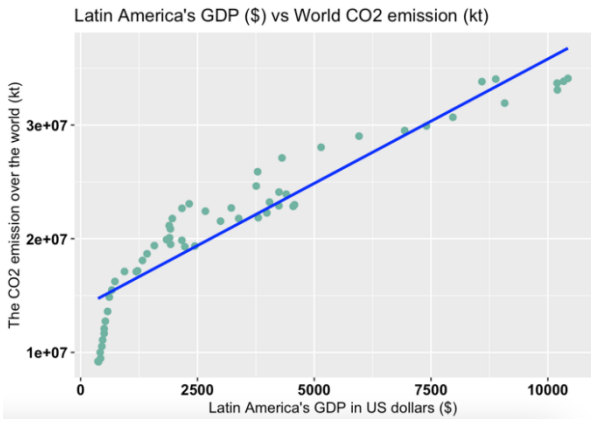


Figure 10. Latin America's GDP ($) VS World CO_2 emission (kt)

Table 5. Latin America's GDP ($) VS World CO_2 emission (kt)

Residuals:				
Min	1Q	Median	3Q	Max
-5588290	-1582416	449304	1724418	4062284
Coefficients:				
	Estimate	Std. Error	t value	Pr(>|t|)
(intercept)	1.393e+07	5.178e+05	26.89	<2e-16
LA_gdp	2.189e+03	1.139e+02	19.21	<2e-16
Residual standard error: 2552000 on 55 degrees of freedom				
Multiple R-squared: 0.8703, Adjusted R-squared: 0.8679				
F-statistic: 369 on 1 and 55 DF, p-value: < 2.2e-16				

Figure 10 and table 5 show the relationship between GDP in Latin America and world CO_2 emission, the relationship is positive as previous figures showed. In Latin America, one unit increase in its GDP will raise 2189 unit increased in world CO_2 emission. Comparing with European Union, Latin America contributes more negative effects to the world GDP. In the table above, the R-squared is 0.8679, which is big enough to summarize the likely lie observations on the regression. Yet, the R-square is smaller than the European Union, showing the residual or error is larger at this point. The p-value is small enough to reject the null hypothesis again. The argument also reflects this from Fuinhas et al. [7], in which the CO_2 emission for three decades is more than double while the policymakers are pursuing the development of economies. To develop the economies without damaging the environment, they suggest that the policies and strategies regarding renewable resources can effectively reduce CO_2 emission and developing economies.

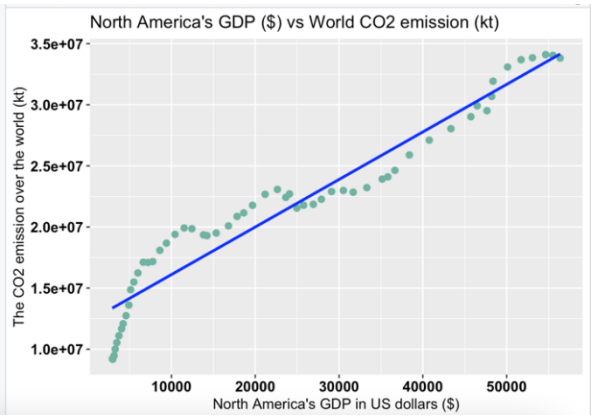


Figure 11. North America's GDP ($) VS World CO_2 emission (kt)

Table 6. North America's GDP ($) VS World CO_2 emission (kt)

Residuals:				
Min	1Q	Median	3Q	Max
-4205640	-1257149	295726	1689080	3221864
Coefficients:				
	Estimate	Std. Error	t value	Pr(>|t|)
(intercept)	1.222e+07	4.436e+05	27.54	<2e-16
NA_gdp	3.891e+02	1.513e+01	25.72	<2e-16
Residual standard error: 1963000 on 55 degrees of freedom				
Multiple R-squared: 0.9232, Adjusted R-squared: 0.9219				
F-statistic: 661.6 on 1 and 55 DF, p-value: < 2.2e-16				

In North America, as one unit increased in the GDP, that will have 389.1 unit increased of the world CO_2 emission, which is lower than both Latin America and European Union. As the p-value is extremely low, and that is sufficient to reject the null hypothesis. At the same time, the adjusted R square is 0.9219, showing the majority of observations close to the regression line. Similar to Dogan et al. and Fuinhas et al., Soytas et al. [8] analyzed the carbon emissions in the United States, and they found out that the CO_2 emission in the US largely depends on energy consumption in the long run; the decrease of energy consumption will cause the reduction of CO_2 emission. This suggests that the government should well-utilize the natural resources friendly by improving the technology, rather than heavily relying on fossil fuels.

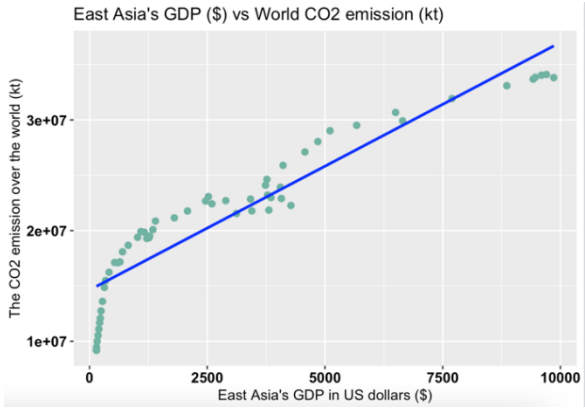


Figure 12. East Asia's GDP ($) VS World CO_2 Emission (kt)

Table 7. East Asia's GDP ($) VS World CO_2 Emission (kt)

Residuals:				
Min	1Q	Median	3Q	Max
-5792179	-1930618	563961	2066759	3094911
Coefficients:				
	Estimate	Std. Error	t value	Pr(>|t|)
(intercept)	1.464e+07	4.855e+05	30.15	<2e-16
EA_gdp	2.236e+03	1.152e+02	19.41	<2e-16
Residual standard error: 2529000 on 55 degrees of freedom				
Multiple R-squared: 0.8727, Adjusted R-squared: 0.8703				
F-statistic: 376.9 on 1 and 55 DF, p-value: < 2.2e-16				

In East Asia, 2236 unit increase in CO_2 emission as one unit increase in the GDP of East Asia. Note that Latin America has a 2189 unit increase as one unit increase in its GDP. Thus, East Asia contributes the most CO_2 emission as its GDP is growing. The residual is relatively large compared with other nations, showing that the ratio, CO_2 emission over the world in terms of East Asia's GDP, is not stable. Based on the figure with a regression line, most of the observations are above the regression line. In recent years, however, there is the trend the ratio starts to decline in the set of [7500, 10000] in GDP. One reason is the government paying attention to the environmental issue, and the plan of carbon neutrality is implemented currently. Based on

the research from Timilsina et al. [9], the transportation energy intensity is the main effect to boost CO_2 emission. Some countries such as Korea, Japan, China already implement the action to limit fuel economy standards, causing the reduction of transportation energy intensity. This is what other countries in Asia should pay attention to.

Comparing and contrasting all these four regions shows a positive relationship, which is the same result as the analysis of the relationship between world CO_2 emission and world GDP. Accordingly, the region is not a confounding variable. In these four regions, East Asia and Latin America emit more CO_2 emissions than North America and European Union. One reason is East Asia and Latin America are currently still developing the nation rapidly, and the development inevitably emits CO_2 emission.

The detail that affects CO_2 emission and GDP depends on the unique local situation. However, it is a good idea to use renewable energy to replace fossil fuels because energy is an important factor regarding both carbon emission and GDP. To effectively use renewable energy as a substitute for fossil fuel, the improvement of technology is mandatory. For example, the Chinese government encourages people to purchase electrical vehicles by offer subsidies to stimulate purchasing power. In 2009, He et al. [10] declared that China had implemented some strategies to reduce CO_2 by installing nuclear energy, wind power, biomass-based power, and biofuel. However, China still experiences industrialization over 2-3 decades, and abundant energy consumption is unavoidable. Therefore, practicing the strategies is not equal to control the CO_2 emission immediately because the country still needs the energy to develop. Still, it will have a positive impact in the future. Accordingly, the US must plan to achieve zero carbon emissions by 2050 and China to make a plan to achieve zero carbon emissions by 2060.

4. CONCLUSION

In conclusion, the region is not a confounding variable because they show the negative relationship between the world GDPs per capita growth and "regional" CO_2 emission per capita. For East Asia and North America, we have a p-value that is greater than 5%. The main reason is a limitation of sample size for these two regions. But overall, it won't affect the result of this report. We have clearly seen that the CO_2 emissions per capita would negatively impact the GDP per capita growth. On the other hand, the environmental issue has negatively impacted our economic benefit.

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