INTERACTION EFFECT OF ECONOMIC ASPECTS ON ENVIRONMENTAL QUALITY IN G20 COUNTRIES

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Abstract. Climate change is one of the biggest challenges facing the world today, and carbon dioxide (CO2) emissions have become a major focus of efforts to understand and address the impacts of climate change. World Bank data shows that CO2 emission levels are still volatile, which can create economic uncertainty, especially in energy and environment-related sectors. This study adopts a quantitative approach using secondary data sourced from the World Bank to analyze the effect of several economic factors on CO2 emissions in 19 G20 member countries during the period 2012-2021. The type of data used is panel data which is a combination of time series data and cross section data. The analytical method applied is Generalized Method of Moments (GMM) for dynamic panel data. The results of the two-step GMM analysis reveal the following findings: Foreign Direct Investment (FDI) has a negative relationship with CO2 emissions, indicating that an increase in the value of FDI can result in a decrease in CO2 emissions. Economic growth rate also has a negative impact on CO2 emissions, while urbanization rate has no significant effect. Household consumption has a positive relationship with CO2 emissions, indicating that an increase in household consumption can increase CO2 emissions. Meanwhile, trade balance has no significant impact on CO2 emissions. Significance analysis shows that FDI, economic growth rate, and household consumption have a significant influence on CO2 emissions, while urbanization rate and trade balance are not significant. These results provide insight into the factors contributing to CO2 emissions in G20 countries and can be the basis for sustainable policy development.
Keywords: C02 emissions; G20 countries; Generalized Method of Moments, Foreign Direct Investment (FDI); economic growth rate; urbanization rate; household consumption; trade balance.

1 Introduction

Climate change is one of the biggest challenges facing the world today, and carbon dioxide (CO2) emissions have become a major focus of efforts to understand and address the impacts of climate change. Recent data shows that CO2 emission levels are still volatile, which means that it can create economic uncertainty, especially in energy and environment-related sectors. (Sari & Khoirudin, 2019) *Although the poverty rate in Indonesia for several years has always decreased. Ch*anges in energy policy, fuel prices, and global economic impacts can occur as a result of these fluctuations. This is due in no small part to energy combustion and industrial activity around the world. This has led to serious concerns about global climate change. In

response, the international community committed to addressing this challenge through the UN Sustainable Development Agenda, with the 13th SDG specifically targeting "taking urgent action to combat climate change and its impacts." The 13th SDG reflects global awareness of the urgency of reducing CO2 emissions as a key step in responding to climate change. High CO2 emissions are recognized as a major contributor to global warming and climate change. Therefore, global efforts to achieve this target require cross-border collaboration and effective policy implementation at all levels, including changes in industrial practices, development of renewable energy, and investment in clean technologies. It is important to recognize that understanding and addressing this issue must be sustainable. Technological innovation, changes in consumer behavior, and full support from governments and the private sector are required to achieve significant emissions reductions. In this context, realizing the 13th SDG is not just about protecting the environment, but also making a positive contribution to global well-being and long-term resilience to climate change. Awareness and collective action are key to realizing the changes needed to sustain the planet.(Ahdiat, 2023). The open economy adopted by most countries in the world is the basis for each country to build bilateral relations (Kartikasari & Khoirudin, 2022). Since the start of the reform era in 1998, Indonesia has advanced towards an era of openness (Khoirudin, et.al. 2022).

The pace of economic growth plays an important role in the context of responding to climate change and achieving SDG 13. In many cases, rapid economic activity is often associated with increased CO2 emissions. Therefore, a key challenge is to align economic growth rates with emission reduction goals to achieve sustainability between economic development and environmental protection. Economic growth rate is an important indicator of a country, however, rapid economic growth sometimes leads to environmental degradation caused by increased CO2 emissions. Economic development that pursues economic benefits often ignores its impact on the surrounding environment. Development that originally aimed to improve the welfare of mankind actually damaged the joints of life support (environmental quality). Economic development that runs to improve the quality and sustainability of humanity grows inversely proportional to the quality of the environment. The degradation of urban quality is closely related to the use of energy that is not environmentally friendly in the process of economic development. (Fauzi, 2017). The rapid development of the industrial revolution has caused changes in many ways changes in various things. The economy is no exception (Khoirudin & Lubis, 2021).

Resarch of (Onofrei et al., 2022) It also shows that as income levels rise, economic growth rates will contribute to an increase in CO2 emissions, which in turn increases the demand for environmental protection. This highlights the importance of designing effective environmental policies to reduce emissions during periods of economic growth. The situation becomes more complex when applied to the G20 countries, the world's largest economic group. The G20 countries, comprising major economic players, have a major impact on the growth rate

of the global economy. However, each G20 country has its own challenges and policies in managing the relationship between economic growth and environmental quality.
According to the Ministry of Finance of the Republic of Indonesia, the G20 or Group of Twenty is a major forum for international economic cooperation consisting of 19 countries and 1 European Union institution.

G20 member countries are not only faced with the challenge of achieving sustainable economic growth rates, they are also faced with the challenge of reducing CO2 emissions. They must find a balance between the need to create jobs, increase production, and improve economic welfare with the responsibility to protect the environment and reduce CO2 emissions. Reducing CO2 emissions requires investment in environmentally friendly infrastructure, such as sustainable transportation, renewable energy, and green buildings. G20 countries face the challenge of allocating sufficient funds and resources to build infrastructure that supports the reduction of CO2 emissions. Lack of adequate investment and financial support can be an obstacle to adopting sustainable solutions.(Winda & Falianty, 2023)

In 2015, the Paris Agreement was signed, which aims to address environmental issues by requiring every country to contribute to efforts to reduce global temperature rise. In the agreement, it was decided to set the limit of global warming at 1.5 degrees Celsius. It is expected that cooperation between countries can support the development of environmentally friendly infrastructure, in line with the agreement's goal of reducing global warming and the impacts of climate change. The collaboration includes its support for clean technology and technology transfer to developing countries. In addition, there are efforts to encourage developing countries to obtain financial support through investment projects that focus on reducing environmental impacts. A significant increase in Foreign Direct Investment (FDI) is considered to have a negative impact on the environment as it goes hand in hand with high industrial productivity and generates CO2 emissions. Although the growth of FDI flows provides benefits to the economy, we cannot ignore the fact that it has an effect on the environment when any level of productivity does not consider its impact on the environment. For the record, G20 member countries account for almost more than ¾ of the world's total CO2 emissions. In addition, the important role of G20 member countries in helping economic development in various countries makes this research will focus on analyzing the Direct Investment made by G20 countries and its relationship with the level of CO2 gas emissions produced.. (Winda & Falianty, 2023)

Research of (Huang et al., 2022) shows that an increase in Foreign Direct Investment (FDI) inflows contributes positively to an increase in carbon emissions, implying that the higher the FDI inflows, the G20 economies produce more carbon dioxide. Regarding the path of influence, the results show that both economic development and regulatory quality reduce the impact of FDI inflows on carbon emissions. This implies that with higher levels of economic development in G20 economies, FDI inflows are more likely to reduce carbon emissions. Correspondingly, with higher levels of regulatory quality in G20 economies, FDI inflows make a positive contribution to reducing carbon emissions. Foreign investment can help increase a

country's production capacity. With increased production capacity, the country can meet domestic and international demand without relying too much on imports. This can contribute to an improved trade balance.

A country's trade balance has a significant impact on greenhouse gas emissions, especially carbon dioxide (CO2). When a country experiences a trade balance deficit, it means that it imports more goods and services than it exports. The production and transportation of these imported goods often involves intensive use of fossil energy, which can lead to increased CO2 emissions. Conversely, a trade balance surplus, where the country exports more than it imports, may indicate that the domestic economic sector is more efficient and oriented towards environmentally friendly technologies. Therefore, trade balance not only reflects economic equilibrium, but can also give an idea of the level of CO2 emissions associated with a country's trade activities. Awareness of this relationship is increasingly important in the context of global climate change, given that changes in trade patterns can have significant implications for greenhouse gas emissions mitigation efforts.(Long et al., 2018)

On the other hand, a trade balance deficit, which reflects high imports, can encourage economic sector growth in urban areas, as demand for imported goods and services can create job opportunities in the distribution, trade and service sectors. This can be a driving factor for urbanization, with people migrating to urban areas to seek employment in international trade-related sectors. (Long et al., 2018)

Urbanization tends to result in increased mobility and transport use. An increase in population in urban areas can result in an increase in demand for transportation, especially personal transportation and freight transportation. If a country experiences rapid urbanization and lacks efficient transport infrastructure, traffic congestion and heavy use of private motor vehicles can increase CO2 emissions.

Research result (Chen et al., 2022) also shows that urbanization contributes positively to carbon emissions. This shows that with urbanization, there is an increase in carbon emissions. In other words, the higher the level of urbanization, the greater the carbon emissions. This is in line with the finding that rapid urban growth is often associated with increased fossil energy use and human activities that contribute to increased greenhouse gas emissions. Therefore, urbanization can be considered as a factor that has the potential to increase environmental impacts, particularly in terms of carbon emissions.

Growth in urbanization is usually accompanied by an increased demand for energy to meet the needs of households, businesses and industries in urban areas. People in urban areas tend to have higher consumption levels, including the use of electronic goods, personal vehicles, and other energy-intensive services. Increased household consumption can be a significant factor in increased energy demand and CO2 emissions. In research (Liu et al., 2021) shows that household consumption positively affects carbon emissions in both the short and long run, reflecting that increased consumption activities at the household level contribute to carbon dioxide (CO2) emissions.

In the research on "The Interaction Effect of Economic Aspects on Environmental Quality in G20 Countries," a number of academic issues need to be addressed. While economic growth rates are often associated with increased CO2 emissions, questions arise regarding the impact of FDI on economic structure and the environment. Trade balances reflect the relationship between exports and imports, raising questions about the impact of imports of high-emitting goods on environmental quality. Urbanization, which is often accompanied by increased energy consumption and infrastructure development, can be a major contributor to CO2 emissions. Household consumption, which tends to increase with the pace of economic growth, is also an important factor in the context of environmental impact. In addition, the complexity of interactions between economic variables and methodological considerations in data analysis are also challenges that need to be addressed in this study. Therefore, an in-depth understanding of these issues will help formulate more focused research objectives and more precise hypotheses.

2 Literature Review & Hypothesis Development

(Kementerian PPN, 2020) explains that emissions refer to the release of greenhouse gases into the atmosphere that occurs through the decomposition of organic matter by microbes, producing CO2 or CH4 gas. The process of burning organic matter produces CO2, while CO2 itself is a colorless and odorless gas. This gas is formed through various processes, including the combustion of fossil fuels such as oil and natural gas, the burning of organic materials such as forests, the decomposition of organic materials, and volcanic eruption activities. Carbon dioxide (CO2) is a chemical compound formed from two oxygen atoms bonded with one carbon atom. At standard temperature and pressure, CO2 is gaseous and exists in the earth's atmosphere. In addition, CO2 is a colorless and odorless gas, which can be produced by all living things, plants, fungi, and microorganisms. The burning of fossil energy is also a source of CO2 production as a side effect.

Pollution Havens theory states that Foreign Direct Investment (FDI), through multinational corporations, plays a role in reducing emission levels in the host country by implementing high production standards and advanced technology. According to Lee, described in the study, Multinationals' investments in other countries can benefit the host country through the positive impacts that come from these investments. First, multinationals contribute to knowledge transfer to the host country by improving skills, management, and better operational practices in the production process. Second, multinationals bringing new ideas and technologies into the production process in the host country can stimulate competition among similar industries in the country. This encourages those industries to continuously improve productivity to enhance their competitiveness. FDI, thus, facilitates faster industrial development in the host country.

The EKC (Environmental Kuznets Curve) hypothesis explains economic growth and CO2 emissions. That initially, economic growth will lead to increased environmental degradation. This happens because countries tend to focus on increasing production without paying attention to environmental impacts. The continuous production process can then result in environmental degradation, including pollution to land, water, and air. However, at a certain point, economic growth is expected to bring awareness to society of the importance of good environmental quality. This point is known as the turning point, where economic growth is expected to reduce environmental degradation. (Shaharir & Alinor, 2013).

The effect of Foreign Direct Investment (FDI) on CO2 emissions has complex dynamics that are highly dependent on a number of factors, including government regulations, economic sectors, and production practices of foreign companies. Research shows that the relationship between FDI and CO2 emissions can be variable. For example, foreign companies that implement cleaner and more efficient production technologies can help reduce CO2 emissions, making a positive contribution to the environment. In addition, the transfer of technology and management practices brought by FDI can improve efficiency and environmental impact. However, it should be noted that the impact of FDI also depends on the economic sector invested in and the government's environmental policies.(Kurniawan & A'yun, 2022). FDI can accelerate the growth of resource- and energy-intensive sectors, which may increase CO2 emissions. Therefore, strict environmental regulations and policies that favor clean technologies can play an important role in steering the impact of FDI on CO2 emissions in a more positive direction. (Winda & Falianty, 2023)

As in research (Huang et al., 2022) that FDI flows make a positive contribution to carbon emissions, implying that as FDI flows increase, G20 economies emit more carbon dioxide. Although FDI flows have proven to be positive for economic growth, they can damage the environment, thus reducing the quality of economic development. In this study, FDI flows are positively related to carbon emissions. However, for the high development levels of the G20 economies, FDI flows, in turn, reduce their carbon emissions. Therefore, it is important for a country to pay more attention to the quality of economic development, which helps reduce carbon emissions caused by FDI flows.

And also in the Pollution Haven Hypothesis has a significant impact on CO2 emissions, especially since shifting production or investment to countries with lower environmental regulations can increase the level of carbon dioxide emissions. The countries that companies go to with more relaxed regulations may not impose strict environmental controls, allowing companies more freedom to carry out industrial activities that could be detrimental to the environment. So, increased FDI can be a positive contributing factor to increased CO2 emissions in host countries, especially if the investing companies do not practice sustainable production standards or use cleaner technologies.

The rate of economic growth shows variations in all economic activities including the ability to show how a country produces goods and services, the rate of economic growth also

shows the business cycle which is likely to affect the performance of a country's Institutions.(Salim & Suripto, 2023)

Increased economic growth rates can accelerate industrial activity and energy consumption, which in turn can result in increased CO2 emissions. In this context, it should be recognized that high economic growth rates often positively impact CO2 emissions in an unsustainable way. For example, a rapidly expanding industrial sector that relies on fossil resources to meet its energy needs can lead to increased greenhouse gas emissions. While energy efficiency and environmental policies can play a role in mitigating these impacts, the positive relationship between economic growth rates and CO2 emissions suggests that the challenge of achieving sustainable growth is increasingly complex. Therefore, it is important to implement policies that not only stimulate economic growth but also ensure that growth is environmentally friendly (Febriyastuti Widyawati et al.).

Research results (Onofrei et al., 2022) show that poorly managed economic growth can increase CO2 emissions, and this relationship is shown to be statistically significant. On average, a 1% change in GDP leads to a 0.072 change in CO2 emissions. Co-integration of variables suggests a long-term relationship, highlighting the need to strengthen waste management strategies and further analyze pollutant emissions that impact climate change and global warming.

Penel. The influence of urbanization levels on CO2 emissions is an important aspect in the context of urban growth and its impact on the environment. Urbanization, which includes the increase in population in cities and the development of urban infrastructure, can have a significant effect on CO2 emissions. For example, high levels of urbanization are often associated with increased industrial activity, transportation, and energy consumption, which in turn can generate greenhouse gas emissions. Urbanization is not only a demographic phenomenon but can also have a direct positive impact on CO2 emissions. As urbanization rates rise, infrastructure growth and population mobility tend to increase, triggering increased fossil energy use and, consequently, higher CO2 emissions. (Huang et al., 2022)

The study (Huang et al., 2022) presents an in-depth analysis of the effect of urbanization on carbon emissions, showing that the relationship between the two is nonlinear, forming an inverted U-shaped curve. Specifically, the findings show that in the early stages of urbanization, there is an increase in carbon emissions as the level of urbanization increases. This indicates that urban growth and industrial activities in the early stages of urbanization may contribute to increased carbon emissions. However, by reaching a certain point, reflected by the peak of the inverted U-curve, further urbanization can be associated with a decrease in carbon emissions. The average position of Organization for Economic Cooperation and Development (OECD) countries is to the left of the curve, suggesting that at lower levels of urbanization, further increases in urbanization tend to increase carbon emissions. The analysis details the link between urbanization and economic development, highlighting the existence of an urbanization tipping point where increasing urbanization no longer significantly increases carbon emissions.

These results provide important policy implications, emphasizing the importance of viewing urbanization as an opportunity to steer urban growth towards becoming more sustainable and environmentally friendly, especially in the advanced stages of the inverted U curve.

The influence of household consumption on CO2 emissions is an important concern in the context of climate change and environmental sustainability. High household consumption tends to correlate with increased demand for energy and goods, which in turn can lead to significant CO2 emissions. As household consumption levels rise, the demand for energy to meet daily needs, transportation, and household maintenance also increases. In general, this increase in consumption often has a positive impact on CO2 emissions. Factors such as the purchase of consumer goods, personal vehicles, and energy-intensive lifestyles can be the main causes of the positive relationship between household consumption and CO2 emissions. Therefore, efforts to reduce the impact of CO2 emissions from household consumption are crucial in achieving environmental sustainability.

The consumption function in Keynes' economic theory, which explores the relationship between national income and consumption expenditure, has an impact that can be linked to CO2 emissions. When national income increases and people have high levels of consumption expenditure, this can trigger growth in economic activity. Increased economic activity is often followed by increased energy use, especially if the energy sources used tend to be fossil-based. In other words, high consumption levels and rapid economic growth can lead to increased CO2 emissions due to the high energy intensity of economic activities. Therefore, when we consider the Keynesian consumption function, we can understand that changes in consumption levels and national income can have a direct impact on CO2 emissions, especially if the dominant energy source is fossil.(Wahyuni & Sukarniati, 2018)

The effect of trade balance on CO2 emissions is a focus of attention in the study of the impact of the global economy on the environment. A high trade balance, which reflects a country's trade surplus, often has a positive impact on CO2 emissions. (A'yun & Khasanah, 2022). When the level of trade balance increases, a country's exports and imports tend to increase, impacting production and consumption activities. Increased exports can lead to increased industrial production and activity, which often relies on fossil energy. The same goes for imports, which can reflect increased consumption and production in other countries that may have lower environmental standards. As a result, high trade surpluses can contribute to increased CO2 emissions. (Puspita & Hartono, 2021).

While a positive trade balance can bring economic benefits, it is important to note that it can be a trade-off between economic growth and environmental preservation. (Long et al., 2018). In a context that supports the positive relationship between international trade and carbon emissions, this study shows that China and Japan play a constructive role in the global framework. Although China has a high carbon emission intensity, its declining intensity shows efforts in reducing environmental impacts. As a net carbon exporter, China makes a positive contribution in terms of providing goods and products to meet the needs of international

consumers. On the other hand, Japan, with a lower emissions intensity, achieved a net reduction in emissions through international trade, creating a positive impact on global emissions levels by relying on clean production from its trading partner countries. Thus, despite efforts to reduce emissions intensity in China, their involvement in international trade has a positive impact on climate change and global emissions. (Ruyin Long, 2018). Company size is an aspect that is considered for a number of investors in deciding whether to invest (Laveda & Khoirudin, 2020).

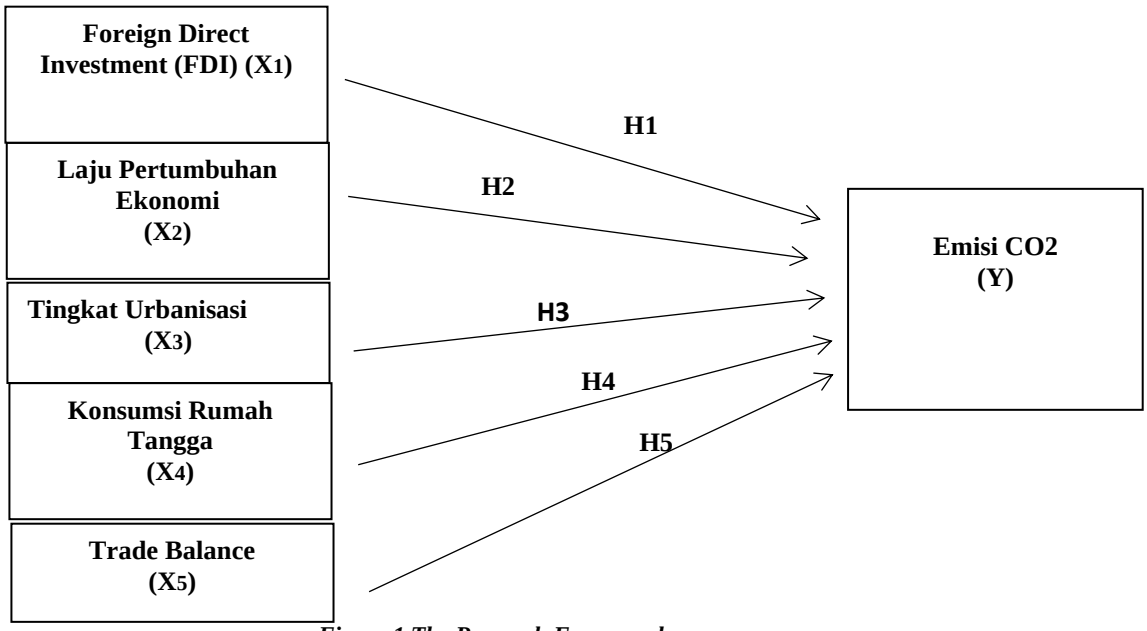

Figure 1 The Research Framework

3 Research Methodology

A quantitative approach was chosen and used in this study through secondary data sourced from the World Bank. The type of data in this study is secondary data in the form of panel data. The panel data in this study is a combination of time series data in the period 2012-2021 with cross section data on 19 G20 member countries. This research applies a quantitative approach by utilizing dynamic panel data and applying the Generalized Method of Moments (GMM) method. This study chose the Generalized Method of Moments (GMM) method as an analytical approach because there are several problems that hinder the fulfillment of classical assumptions in the model. Classical assumptions such as homoscedasticity, normality, and the absence of autocorrelation are often difficult to fulfill perfectly in the context of empirical data. (Yuniarti & Sukarniati, 2021)Therefore, the GMM method is considered more flexible and able to handle the imperfections of these assumptions. The panel data regression analysis test will be carried out by selecting the best model consisting of model estimation, model fit test, classical assumption test, statistical test, and statistical test. (zakiyyah & Wahyuni, 2021). By looking at

the data processing results, it can be seen that the comparison of model performance using the GMM method is better than other approaches, especially when compared to models that rely on classical assumptions. The GMM method allows for a more adaptive model fit to heteroscedasticity and non-normal distributions in the data, thus providing more consistent and efficient parameter estimates.

Then the econometric model in this study is as follows:

$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \epsilon$

Description :

Y	= CO2 Emissions
X1	= FDI (Foreign Direct Investment)
X2	= Economic Growth Rate
X3	= Urbanization Rate
X4	= Household Consumption
X5	= Trade Balance
$\beta 0$	= Constant
$\beta 1, \beta 2, \beta 3, \beta 4, \beta 5$	= Regression coefficient
ϵ	= Error Term

4 Result and Discussion

The X1 variable shows an average of 24.07272 with a standard deviation of 1.339769. In this case, the average value which is greater than the standard deviation indicates that the data distribution tends to be normal. Variable X2 has an average of 2.144116 and a standard deviation of 3.507763. The significant difference between the mean and standard deviation indicates a deviation in the distribution of variable X2. For variable X3, an average of 75.41617 was found with a standard deviation of 14.03296. The moderate difference between the mean and standard deviation indicates that the data distribution tends to be normal. Variable X4 shows a mean of 56.49185 and a standard deviation of 8.348046. In this case, a mean value greater than the standard deviation indicates that the data distribution tends to be normal. Finally, variable X5 has an average of 52.69944 and a standard deviation of 17.921. As with variable X2, the sizable difference between the mean and standard deviation indicates a deviation from normal distribution on this variable.

Table 1 Descriptive Analysis

Variable	Obs	Mean	STd. Dev.	Min	Max
Y	190	16.36188	1.299611	10.80241	18.86427
X1	188	24.07272	1.339769	17.36803	26.96048
X2	190	2.144116	3.507763	-11.03086	11.3535
X3	190	75.41617	14.03296	31.634	92.229
X4	190	56.49185	8.348046	28.30923	69.47018

X5	190	52.69944	17.921	22.48623	105.4583

This study underwent a change in the logarithmic form of the variables in order to improve the distribution of the data and facilitate the interpretation of the results. The two main variables involved in this analysis are the dependent variable, y, which is measured in tons, and the independent variable, x1, which is measured in US Dollars. unit changes were applied to the logarithms of the variables to facilitate interpretation of the results. The variable y, which was originally measured in tons, after the change in logarithmic form is measured in percent. Similarly, the variable x1, which was originally measured in US Dollars, after the logarithmic change, is also measured in percent. This change in units helps overcome scale issues and allows for easier comparisons between the variables.

Table 2 Change of Logarithmic Form of Variables

Original Variable	Initial Unit	Logarithm Variable	Change Unit
y	ton	Y	persen
x1	US Dollar	X1	persen

Based on the results of the two-step General Method of Moment (GMM) approach, the following results can be interpreted: The coefficient value of variable X1 or Foreign Direct Investment (FDI) of -0.1814353 indicates that there is a negative relationship between FDI and CO2 Emissions. Which means that when the value of FDI increases by 1%, it can expect a decrease in the average value of CO2 emissions by 0.1814353%. The coefficient value of the X2 variable or the economic growth rate of -0.0569651 means that there is a negative relationship, meaning that every 1% increase in the value of the economic growth rate will reduce the level of CO2 emissions by 0.0569651%. The coefficient value of variable X3 or urbanization level is -0.011618, every one unit increase in the urbanization level index can reduce the value of CO2 emissions by 0.011618%. The coefficient value of variable X4 or household consumption is 0.01151467, which is positive, indicating that there is a positive relationship between the household consumption variable and the CO2 emission variable, which means that every 1% increase in household consumption, CO2 emissions will also increase by 0.01151467%. The coefficient value of X5 or trade balance is 0.0159524 which is positive. So it can be interpreted that every 1% increase in trade balance value will increase the value of CO2 emissions by 0.0159524%.

Based on the results of the analysis of the effect of FDI (Foreign Direct Investment) on CO2 emissions, the significance value of GMM analysis is 0.312. The significance value of 0.033 <0.05, this indicates that FDI (Foreign Direct Investment) has a significant effect on CO2 emissions in the G20 member countries for the period 2012-2021. Based on the results of the analysis of the effect of economic growth rate on CO2 emissions, the significance value of GMM analysis is 0.000. The significance value of 0.000 <0.05, this indicates that the rate of economic growth has a significant effect on CO2 emissions in the G20 member countries for

the 2012-2021 period. Based on the results of the analysis of the effect of the level of urbanization on CO2 emissions, the significance value of GMM analysis is 0.933. The significance value of 0.933> 0.05, this indicates that the level of urbanization has no effect on CO2 emissions in the G20 member countries for the 2012-2021 period. Based on the results of the analysis of the effect of household consumption on CO2 emissions, the significance value of the GMM analysis is 0.004. The significance value of 0.004 <0.05, this indicates that household consumption has a significant effect on CO2 emissions in the G20 member countries for the 2012-2021 period. Based on the results of the analysis of the effect of trade balance on CO2 emissions, the significance value of GMM analysis is 0.369. The significance value of 0.369> 0.05, this indicates that trade balance has no effect on CO2 emissions in G20 member countries for the 2012-2021 period.

Table 3 GMM Results

Variable	Coeff	z	P>|z|	Description
X1	-0,1814353	-1,01	0,033	Significant
X2	-0,0569651	-2,13	0,00	Significant
X3	-0,011618	-4,38	0,933	Not Significant
X4	0,1151467	2,91	0,004	Significant
X5	0,0159524	0,9	0,369	Not Significant
_cons	18,21989	1,49	0,136	Not Significant

The Sargan test result with a value of 0.9972 indicates the validity of the instruments used in the analysis. Validity is considered fulfilled when the probability value of the Sargan test exceeds the 0.05 threshold. In other words, the instruments are considered effective and relevant in addressing endogeneity issues in the regression model.

Table 4 Sargan Test

Testing	Statistical Value	P-Value
Uji Sargan	16,22887	0,9972

The 2nd order P-value of 0.1412 is greater than 0.05, which implies that there is insufficient evidence to reject the null hypothesis of unautocorrelation in the errors after taking the difference at the 0.05 significance level. Therefore, the model is considered consistent in the context of the Arellano-Bond autocorrelation test.

Table 5 Arellano Bond Test

Testing	Statistical Value	P-Value
1	-1,589	0,1121
2	-1,4713	0,1412

5 Conclusion

This study reveals some significant findings regarding the factors affecting CO2 emissions in G20 countries over the period 2012-2021. First, there is an indication that Foreign Direct Investment (FDI) has a significant influence on CO2 emissions, with a negative relationship between an increase in the value of FDI and a decrease in carbon emissions. The implication is that economic policies that support foreign investment growth can be an effective strategy in achieving carbon emission reduction goals. Secondly, economic growth rate also plays an important role, with the finding that an increase in economic growth rate can contribute to a decrease in CO2 emissions, in line with the concept of the Environmental Kuznet Curve (EKC). However, this result differs from previous studies in the EU, demonstrating the complexity of the relationship across different contexts. Third, the level of urbanization was not shown to have a significant relationship with reducing CO2 emissions, highlighting the complexity of urbanization's impact on production patterns and clean technology adoption. Fourth, the study confirmed a positive relationship between household consumption and increased CO2 emissions, highlighting the role of consumption in shaping the carbon footprint. Lastly, trade balance generally has no significant effect on CO2 emissions, which can be explained by the dynamics of trade tensions and the impact of the COVID-19 pandemic that changed global production and consumption patterns. These findings provide important insights for the development of more effective policies to reduce the environmental impact of economic activities.

This study, while revealing significant findings regarding the factors affecting CO2 emissions in G20 countries from 2012 to 2021, has several limitations. Data limitations are a key concern, as reliance on aggregated or secondary data sources could introduce measurement errors and limit the ability to capture nuanced relationships. Methodological constraints, such as the assumptions inherent in regression analysis, might limit the interpretation of causality and fail to adequately capture non-linear relationships. Furthermore, the temporal scope of the study, which includes significant global economic events like the COVID-19 pandemic, may have distorted normal economic and environmental patterns.

Additionally, the study does not address several possible confounding factors that could influence the relationships between the variables studied. Changes in environmental policies within G20 countries during the study period could have independently influenced CO2 emissions. Technological advancements, particularly in clean technologies and energy efficiency, may have affected emissions trends irrespective of economic factors. Cultural and behavioral factors, including shifts in consumer preferences and attitudes towards sustainability, also play a crucial role in shaping CO2 emissions. Finally, global events such as geopolitical tensions, natural disasters, and other significant occurrences could have impacted trade dynamics and economic activities, thereby influencing emissions in unexpected ways. These considerations highlight the complexity of the relationships studied and underscore the need for

a comprehensive approach in developing policies to reduce the environmental impact of economic activities.

IMPLICATION/LIMITATION AND SUGGESTIONS

This research presents significant implications in the context of environmental policy and sustainable development. The finding that economic policies supporting foreign investment can reduce CO2 emissions provides a basis for governments to consider incentives that support sustainable investment. Similarly, the negative relationship between economic growth and CO2 emissions underscores the importance of sustainable economic growth with a focus on clean technologies. Although urbanization does not have a significant impact, the suggestion to focus on sustainable urban policies, such as public transport and green infrastructure, can guide emission prevention efforts. Meanwhile, the positive relationship between household consumption and CO2 emissions raises the need for consumer awareness of environmental impacts. Nonetheless, this study has limitations, including the use of secondary data that may introduce uncertainty, country-level analysis that may miss regional nuances, and lack of exploration of the mechanism of the relationship. Therefore, future research is recommended to explore primary data, expand the analysis to the regional level, elucidate the mechanism of the relationship, and consider external factors for a more in-depth context.

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