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Income, Trade Openness, and Carbon Emission: Comparative Analysis of Continents and Trade Regions

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Abstract: Trade is one of the significant contributors to carbon emissions because it promotes transportation and merchandise production. With the threat of global warming, it is essential to study how trade influences carbon emissions and what are the potential solutions. This paper tests the correlation between trade openness and carbon emissions in different continents and regions. Using panel data analysis, the regression result suggests that the relationship is positive in Africa, South America, Asia, and North America, while it is negative in Europe and Oceania. Moreover, positive relationships are also observed in afCFTA (African Continental Free Trade Area) and non-afCFTA, while EU (European Union), non-EU regions, GCC (Gulf Cooperation Council), and non-GCC regions display negative trends. The result verified that developed regions are generally more efficient at carbon emissions compared to under-developed ones. Therefore, high-income continents need to aid low-income continents with carbon reduction. Countries located on a low-income continent should insert more effort to reduce emissions when they intend to boost trading with other countries. The regression coefficients also suggest that non-EU and non-afCFTA countries should join the free trade agreements from an environmental aspect. All regions should not neglect emissions when trading and adopt strategies based on local characteristics to combat the increasing global emissions together.

Keywords: carbon dioxide emission, free trade agreements, climate change, trade openness, economic growth

1. Introduction

More and more free trade agreements (FTAs) have been signed over the past decades. Take the year 2020 as an example. In one year, the USMCA (United States-Mexico-Canada Agreement) was signed by NAFTA (North America Free Trade Agreement) players, and RCEP (Regional Comprehensive Economic Partnership) was signed by fifteen major players in Asia. With increasing FTAs entering into force, scholars have raised concerns about trading causing substantial environmental degradation.

FTAs promote international trading, which generates greenhouse gas emissions through the production, transportation, distribution, and consumption of traded goods and services. Additional economic activities caused by the increased income also count for emissions. Admitting that trading causes pollution, the World Trading Organization (WTO) calls for international trade cooperation to make climate actions more effective. Aiming to add to the existing knowledge of climate and

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economy, this paper investigates how trade openness affects carbon emissions. Namely, the paper will shed light on the environmental response with an increase in trade openness and respond to how FTAs affect carbon emissions.

Countries are interested in this information not only because pollution harms the environment, but also because carbon treatments are economically costly. The most efficient negative emissions technology scientists have developed is called direct air capture (DAC). The DAC takes a tank of air and blows it through a solution that contains CO2-capture chemicals to purify the air. The remaining CO2 will be stored underground or used for commercial production. According to the American Physical Society, the DAC process would cost $600 or more per metric ton of CO_2 emissions [1]. Thus, knowing the relationship between trade openness and carbon emissions aids governors in taking both the environmental and economic costs of trading into consideration, and better evaluating their trading strategy.

On top of testing the relationship between trade openness and carbon emissions for regions included in FTAs, this paper will also test the relationship for countries that have not committed to regional FTAs. This relationship is important because non-FTA countries' emissions will create negative externalities to other countries within the same continent. If these countries create a considerable emission outflow, then they could join neighboring trading alliances within the same continent, to advance economically together and decrease the cost of externalities.

2. Literature Review

Trading significantly contributes to global emissions. Research conducted by Copeland et al. found that a fourth to a third of global pollution emissions come from international trade, and the share would increase with time if no strategy is taken [2]. WTO also published a report, stating that about 20% to 30% of global emissions in 2021 were due to the international production and transportation of goods and services [3]. Besides production and transportation, other activities, such as the consumption of global goods and the treatment of invasive species caused by trading, also counts for emissions. As one can see, international trading is still a prominent player in global carbon emissions today. With more and more trade agreements coming into force, managing these agreements to achieve a more sustainable economy is urgent.

Admitting that trade generally results in carbon pollution, the work of environmental economists has started since the 1970s to review globalization, carbon emission, trade policies, and environmental policies. In 1991, Gene M. Grossman and Alan B. Krueger conducted an environmental assessment of NAFTA. The research found that international trading is economically beneficial as it increases GDP per capita. However, it is also environmentally costly for low-income countries as pollutant increase with per capita GDP, while marginal pollutant decreases when the country has a high level of GDP growth. The paper revealed that the environmental consequences of trading vary between different types of economies and trade policies implemented [4]. Then, many works were born to address the environmental consequences of economic growth caused by international trading.

Scholars reported different study results, and the relationship is inconsistent across regions. A paper by Dou Yue et al. found that CO2 emissions increased substantially after the China-Japan-Korea Free Trade Agreement was established and suggested reforms [5]. In contrast, Shahbaz et al. found that greater trade openness decreases the amount of carbon produced in South Africa by lowering the growth of energy pollutants [6]. Then, Ryan et al. suggested that the amount of emissions is indifferent before and after agreements between Chile, USA, and the EU [7]. Finally, another study by Managi showed that the decisive factor is participation in the Organization for Economic Co-operation and Development [8].

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Scholars have not derived a consistent result. The relationship varies depending on each country's political, economic, and social factors. Consequently, instead of staying at the country level, this study addresses the relationship at the continent or regional level. The data used in this study is also recent to provide up-to-date knowledge of the current environmental and economic conditions. The paper would thus contribute to existing literature and knowledge of the subject matter.

3. Data and Method

3.1. Research Data

Information for all 195 countries across the globe is retrieved from the World Bank database. Continent categorizations are North America, South America, Oceania, Asia, Africa, and Europe. Another classification arranges countries based on the FTAs they participate in, as shown in Figure 1. Countries are divided into eight free trade regions: USMCA, Mercosur, European Union, EAEU, GCC, RCEP, SAARC, and afCFTA. Detailed classification can be found in Table 1. The eight regions were chosen because they had the largest trade volume in 2021 and they do not overlap. Countries that do not belong to these eight regions are categorized into Non-USMCA, Non-Mercosur, Non-European-Union, Non-EAEU, Non-GCC, Non-GCEP, Non-SAARC, and Non-afCFTA according to their geographical locations and their potential political interests. For example, Eritrea is not part of the afCFTA. It is in Eastern Africa, and it has a friendly relationship with other African countries. It is thus classified as a non-afCFTA country. A more complicated example is Turkey as it is in the middle of Southeastern Europe and Southwestern Asia. However, since Turkey has been a candidate country to join the European Union since 1999, it is classified under the non-EU category.

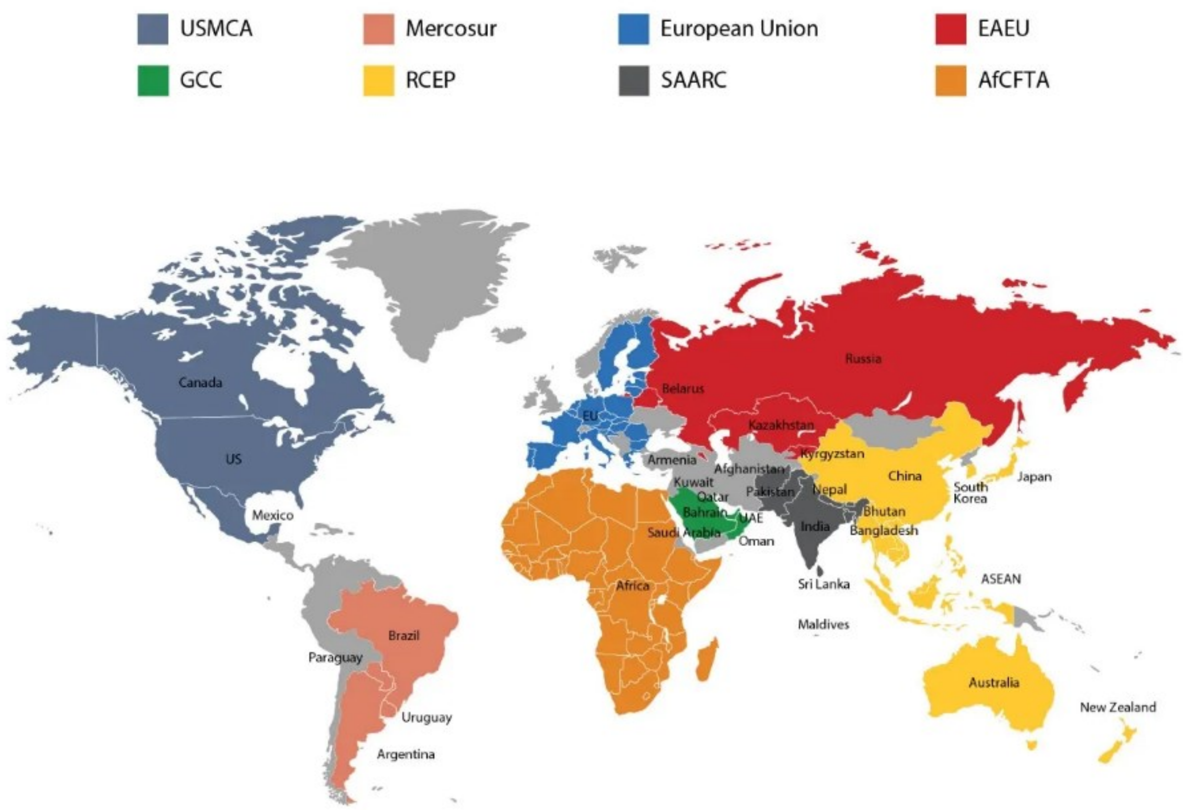

Figure 1: The world in regional free trade agreements.
Source: https://www.silkroadbriefing.com/news/2021/06/03/the-rcep-asias-equivalent-to-usmca-and-the-european-union/

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Table 1: Country classification by eight regional free trade agreements.

FTA Abbreviation	FTA Full Name	Countries Included	Note
USMCA	United States-Mexico-Canada Agreement	United States, Mexico, Canada	Population: 500 million GDP: 24.2 trillion U.S dollars
MERCOSUR	Mercado Común del Sur - Southern Common Market	Argentina, Brazil, Paraguay, Uruguay	Population: 295 million GDP: 2 trillion U.S dollars
EU	European Union	Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden	Population: 448 million GDP: 17.13 trillion U.S dollars
EAEU	Eurasian Economic Union	Russia, Belarus, Kazakhstan, Kyrgyzstan, Armenia	Population: 183 million GDP: 471.8 billion U.S dollars
GCC	Gulf Cooperation Council	Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates	Population: 54 million GDP: 3.464 trillion U.S dollars
RCEP	Regional Comprehensive Economic Partnership	Australia, New Zealand, Brunei, Darussalam, Cambodia, China, Japan, Laos, Singapore, Thailand, Vietnam	Population: 2.6 billion GDP: 26.58 trillion U.S dollars
SAARC	South Asian Association for Regional Cooperation	Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka	Population: 1.88 billion GDP: 4.084 trillion U.S dollars
afCFTA	African Continental Free Trade Area	Egypt, Ethiopia, Gambia, Ghana, Kenya, Rwanda, Niger, Chad, Eswatini, Guinea, Côte d'Ivoire, Mali, Namibia, South Africa, Republic of the Congo, Djibouti, Mauritania, Uganda, Senegal, Togo, Sahrawi Arab Democratic Republic, Sierra Leone, Zimbabwe, São Tomé & Príncipe, Equatorial Guinea, Gabon, Mauritius, Central African Republic, Angola, Burkina Faso, Lesotho, Tunisia, Cameroon, Nigeria, Malawi, Zambia, Algeria, Burundi, Seychelles, Tanzania, Cabo Verde	Population: 1.3 billion GDP: 3.4 trillion U.S dollars

Note: Data for population and GDP are from FTAs' official website.

The study will include data from 1990 to 2019. Data after 2019 are not considered to exclude the effect of COVID-19, which influences both carbon emissions and trade.

This study looks at three variables summarized in Table 2. The amount of CO2 emission is given by Climate Watch Historical GHG Emissions following IPCC guidelines. Trade openness is calculated by adding imports and exports, then dividing by the total amount of GDP.

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Table 2: Variable summary statistics.

Variable	Min	1st Quantile	Median	Mean	3rd Quantile	Max
Carbon Emission (metric tons per capita)	0.00099	0.7473	2.5339	4.3175	6.3505	50.9540
GDP per capita (U.S dollar)	22.8	1035.0	3134.4	9597.4	10549.5	123678.7
Trade openness (in percent of GDP)	0.021	47.920	64.498	76.815	94.970	437.327

3.2. Research Method

In 1991, Grossman and Krueger first proposed that there exists a downward parabola-shaped relationship between economic growth and environmental degradation. Later in 1993, Panayotou conceptualized it into the "Environment Kuznets Curve (EKC)". Based on EKC, the Carbon Kuznets Curve (CKC) hypothesis was developed, which argues that marginal carbon emissions first increase in the early period of GDP growth per capita, then there exists a point after which marginal carbon emissions start to decrease. The general trend then appears to have a concave down U-shape. To capture the quadratic relationship, the initial model takes the following form:

$$C = \alpha + \beta_1 Y + \beta_2 Y^2 + \beta_T T + \mathcal{E} \tag{1}$$

In this model, C stands for carbon emissions, Y stands for GDP per capita, and T indicates trade openness. The estimate for β will capture the change in carbon emission in metric tons per capita with the change in GDP per capita. Similarly, the estimate for β_T will capture the change in carbon emission with the change in trade openness. The squared term Y^2 captures the non-linear relationship between carbon emissions and GDP as represented by the CKC.

However, this original model does not have continent or region specifications as it requires β_T to be the same for all countries ($\frac{\partial C}{\partial T} = \beta_T$). Aiming to answer the research question at the continent and regional level, the two new models are developed to categorize countries based on regions and continents.

$$ln(C_{i,t}) = \alpha + \beta_1 ln(Y_{i,t}) + \beta_2 \ln(Y_{i,t})^2 + \sum_{c\in continent}(\mathcal{T}^c \mathrm{D}_{i,t}{}^c T_{i,t}) + \delta_i + \delta_t + \mathcal{E}_{i,t} \tag{2}$$

$$ln(C_{i,t}) = \alpha + \beta_1 ln(Y_{i,t}) + \beta_2 \ln(Y_{i,t})^2 + \sum_{r\in region}(\mathcal{T}^r \mathrm{D}_{i,t}{}^r T_{i,t}) + \delta_i + \delta_t + \mathcal{E}_{i,t} \tag{3}$$

Equation 2 captures the relationship in the continent level, while Equation 3 captures the relationship at the regional level. In these two models, subscript i indicates country, and t is the time in years from 1990 to 2019. Variables here are $C_{i,t}$, $Y_{i,t}$, and $T_{i,t}$. $C_{i,t}$ stands for the amount of carbon emission of country i in year t. The unit is in metric tons per capita. $Y_{i,t}$ stands for GDP per capita of country i in year t. The unit is in U.S. dollars. $T_{i,t}$ stands for total trade in percent of GDP for country i at time t. The two models have 3 coefficients. β is the correlation coefficient between GDP per capita and carbon emission. $\mathcal{T}^c$ is the correlation coefficient between trade openness and carbon emission at a continent level. $\mathcal{T}^r$ captures the relationship between trade openness and carbon emission in different FTA regions. One of the dummy variables is $\mathrm{D}_{i,t}{}^c$. It equals 1 if the country belongs to the continent that the regression is testing and 0 otherwise. $\mathrm{D}_{i,t}{}^r$ is another dummy variable that equals 1 if the country belongs to the free trade agreement regions that the regression is testing. Other terms in the model are δ_i to control country fixed effect and δ_t to control time fixed effect to capture yearly global and country changes that affect the number of carbon emissions.

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Models 2 and 3 use a log-log relationship to capture the percent-to-percent elasticity between carbon emission, GDP per capita, and trade. The result can then express the proportional relationship between variables and reduce the gap between different scales of data to make them comparable.

4. Regression Result

4.1. Regression Result by Continents

The regression result at the continent level is summarized in Table 3 and Table 4. According to the tables, when GDP per capita increases by 1 percent, keeping everything else constant, the carbon emissions in metric tons per capita are expected to increase by approximately 0.6916%. The result is statistically significant and meaningful. Based on the World Bank Data Base, the world had an average of $11,407.5 GDP per capita and 4.5 metric tons of carbon emission per capita in 2019. Based on the estimates, if the world GDP per capita increases by $114, carbon emission is expected to increase by 0.0311 metric tons per capita.

$\mathcal{T}^{r}$ is the primary variable of interest. Continent Africa is chosen to be the omitted category in this model. As described in Table 4, the regression result suggests that as trade openness increases by 1%, carbon emission is expected to increase by 0.0076% in Africa, 0.0076% in South America, 0.0007% in Asia, and 0.0028% in North America in average, keeping everything else constant. The coefficient of South America is not significantly different from that of Africa at a 0.05 significant level (p-value = 0.071). On the contrary, as trade openness increases by 1%, carbon emission is expected to decrease by 0.0005% in Europe and 0.0041% in Oceania.

By ranking, Africa and South America are the least efficient in emission control when trading. Oceania is the most efficient continent, with the lowest rate of change in percentage emissions per 1% increase in trade openness.

Table 3: Equation 2 regression result at the continent level.

	log (CO_2Emission_pc)		
Predictors	Estimates	Confidence interval	P-value
GDP per capita	0.6916	0.6718 – 0.7114	<0.001
Trade Openness	0.0076	0.0063 – 0.0089	<0.001
Trade Openness * Asia	-0.0069	-0.0084 – -0.0054	<0.001
Trade Openness * Europe	-0.0081	-0.0097 – -0.0066	<0.001
Trade Openness * North America	-0.0048	-0.0071 – -0.0025	<0.001
Trade Openness * Oceania	-0.0117	-0.0149 – -0.0084	<0.001
Trade Openness * South America	-0.0023	-0.0048 – 0.0002	0.071
Observations	4153		
R^2 / R^2 adjusted	0.594 / 0.593		

Note: Statistical significance evaluated using 0.5 critical value.

Table 4: Equation 2 regression result summary.

Predictor	Log-log estimate
GDP per capita	0.6916
Africa	0.0076
Asia	0.0007
Europe	-0.0005

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Table 4: (continued).

North America	0.0028
Oceania	-0.0041
South America	0.0053

Note: South America is not significantly different from the estimate for Africa.

4.2. Regression Result by FTA Regions

The regression at the regional level is summarized in Table 5 and Table 6. The coefficient on GDP per capita increased to approximately 0.2510, which is also statistically significant and meaningful. It indicates that when GDP per capita increases by 1%, carbon emissions are expected to increase by 0.2510% in metric tons per capita.

Table 5 shows the Model 3 regression result. The omitted category in this regression is afCFTA. As trade openness increases by 1%, carbon emissions are expected to increase by 0.0036% in afCFTA and 0.0121% in non-afCFTA. On the contrary, carbon emission is expected to decrease by 0.0059% in the EU, 0.0018% in non-EU regions, 0.0027% in GCC, and 0.0031% in non-GCC regions. The effect size is estimated at 0.0010% in SAARC. However, the estimate is unavailable for countries categorized as non-SAARC because Burma (Myanmar) is the only country in the Indian Sub-Continent that falls within this category. The effect sizes for MERCOSUR, non-MERCOSUR, RCEP, non-RCEP, USMCA, non-USMCA, EAEU, and non-EAEU subgroups are not significantly different from the afCFTA's at a 0.05 significance level (p-value > 0.05).

Table 5: Equation 3 regression result at the regional level by FTAs.

	log (CO_2Emission_pc)		
Predictors	Estimates	Confidence interval	P-value
GDP pc [log]	0.2510	0.2324 – 0.2696	<0.001
Trade Openness	0.0036	0.0025 – 0.0047	<0.001
Trade Openness * EAEU	-0.0003	-0.0040 – 0.0034	0.873
Trade Openness * EU	-0.0095	-0.0110 – -0.0081	<0.001
Trade Openness * GCC	-0.0063	-0.0104 – -0.0022	0.003
Trade Openness * MERCOSUR	-0.0002	-0.0058 – 0.0053	0.941
Trade Openness * Non EAEU	-0.0051	-0.0083 – -0.0018	0.002
Trade Openness * NonafCFTA	0.0085	0.0037 – 0.0132	<0.001
Trade Openness * NonEAEU	-0.0002	-0.0031 – 0.0027	0.913
Trade Openness * NonEU	-0.0054	-0.0077 – -0.0031	<0.001
Trade Openness * NonGCC	-0.0067	-0.0090 – -0.0044	<0.001
Trade Openness * NonMERCOSUR	-0.0030	-0.0069 – 0.0010	0.144
Trade Openness * NonRCEP	-0.0031	-0.0063 – 0.0001	0.055
Trade Openness * NonUSMCA	-0.0010	-0.0037 – 0.0018	0.493
Trade Openness * RCEP	-0.0015	-0.0037 – 0.0007	0.173
Trade Openness * SAARC	0.0069	0.0021– 0.0117	0.005

Table 5: (continued).

Trade Openness * USMCA	-0.0039	-0.0109 – 0.0030	0.266
Observations	3628		
R^2 / R^2 adjusted	0.205 / 0.172		

Note: Statistical significance evaluated using 0.5 critical value.

Table 6: Equation 3 regression result summary.

Predictor	Log-log estimate	Predictor	Log-log estimate
GDP per capita	0.2510		
afCFTA	0.0036	Non-afCFTA	0.0121
EU	-0.0059	Non-EU	-0.0018
GCC	-0.0027	Non-GCC	-0.0031
SAARC	0.0105	Non-SAARC	NA
EAEU	-0.0059	Non-EAEU	0.0035
MERCOSUR	0.0034	Non-MERCOSURE	0.0006
RCEP	0.0021	Non-RCEP	0.0005
USMCA	-0.0003	Non-USMCA	0.0027

Note: EAEU, non-EAEU, MERCOSUR, non-MERCOSUR, RCEP, non-RCEP, USMCA, and non-USMCA are not significantly different from the estimate for afCFTA.

5. Interpretation

5.1. Analysis at the Continent Level and Policy Implications

Among the six continents, Africa and South America have the most significant positive effect size. One potential cause is their low income level. According to the World Bank Data Base, Africa had a $2,194 GDP per capita, and South America had a $8,697 GDP per capita in 2019, ranked as the two lowest continental GDPs per capita. Limited economic resources constrain the two continents from developing sustainably since producing renewable energy is more costly than non-renewable ones. Figure 2 shows global fossil-fuel per-tax subsidies for both production and consumption as a share of GDP in 2020. According to the map, many African countries subsidize fossil fuels extensively. Libya, located in North Africa, spent 16.65% of its GDP on fossil fuel subsidies – the world's largest share of GDP spent on fossil fuel subsidies. After five Middle Eastern countries, Algeria (an African country) is ranked sixth, and Venezuela (a South American country) is ranked seventh (shown in Figure 2). The extensive use of unsustainable energy in electricity, production, and transportation is one of the biggest contributors to inefficient carbon emissions when trading. Grossman and Krueger also argued that dirty industries in low-income countries tend to be less emission-efficient [4].

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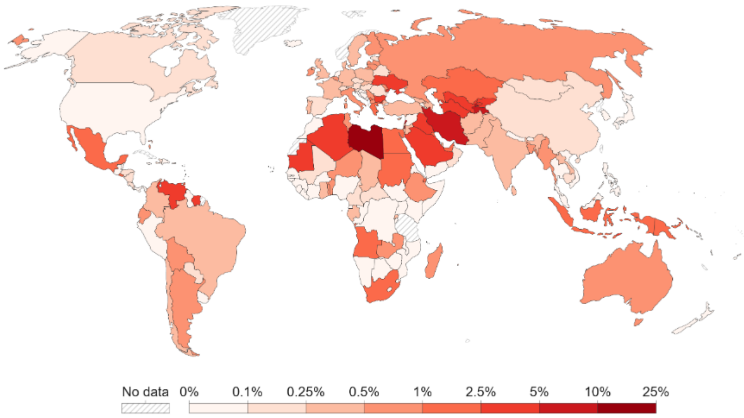

Figure 2: Fossil-fuel subsidies as a share of GDP, 2020.
Source: https://ourworldindata.org/grapher/fossil-fuel-subsidies-gdp

On the contrary, carbon emissions are expected to decrease when Europe and Oceania experience an increase in trade openness. One possible explanation is that the two continents have the economic ability to invest in a sustainable economy. Indeed, Australia and New Zealand had the largest GDP per capita, followed by North America and Europe in 2019, according to the World Bank Data Base. As a result, trade openness decreases carbon emissions in high-income countries. This phenomenon aligns with the phenomenon observed by many scholars as carbon transfer in international trade. Low-income countries generally have lower environmental regulations and standards compared to higher-income countries. Through the global supply chain, developed countries often transfer or outsource their pollution and polluting industries to countries of lower income. Thus, trade openness reduces carbon emissions for developed countries and negatively impacts emerging countries.

The above analysis has several policy implications. Firstly, countries on different continents must cooperate to reduce global carbon emissions. Those with high-income levels (such as ones geographically located in Europe and Oceania) already have the power and facility to decrease carbon emissions when increasing trade with other countries. Therefore, these countries could help those who are poor economically. Helpful strategies include strengthening high-income countries' commitment to international treaties, such as the Paris Agreement, and providing financial, technical, and capacity-building support to countries in need. Secondly, countries located in Africa and South America should exert more efficient environmental management efforts. Admitting that low-income countries may not have the economic incentive to impose carbon-emitting regulations, countries should still promote the use of clean and renewable technologies in production while reducing investment in fossil fuel subsidies.

5.2. Analysis at the Regional Level and Policy Implications

To start the analysis, both the EU and non-EU regions reduce emissions while increasing trade openness. This coincides with the finding in section 5.1. Europe is a well-developed continent with the financial capacity for green development. By benefiting economically from international trade, countries can re-invest in sustainable industries. Within the continent, the EU region is more efficient at carbon emissions than the non-EU region. One significant reason is the EU's shared economy, which enables efficient carbon transfer between countries. Moreover, the agreement is beneficial economically. Members enjoy price stability, product diversity, economic growth, efficient financial markets, job opportunities, and more significant influence in the global economy. Indeed, it is expected that the EU's GDP would decrease by 9% if there had been no single market integration [9]. With an improving economy, countries produce less emissions with an increase in GDP per capita.

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Furthermore, both afCFTA and non-afCFTA regions increase carbon emissions with an increase in trade openness. This result also reflects that Africa is not an emissions-efficient continent as discussed in section 5.1. When African countries openly trade with other countries, developed ones tend to transfer emissions into Africa, increasing emissions. However, the afCFTA region is more efficient in carbon emissions compared to the non-afCFTA region. From an environmental perspective, the agreement shortens the supply chain, boosts intra-regional trade, and strengthens the regional energy market, all of which reduce damage to the global environment in the long run. From an economic perspective, there are expected to be 81% more intra-continental exports and 19% more exports to countries on other continents. The World Bank 2020 report predicted that the afCFTA will bring a real income benefit of 450 billion dollars by 2035 [10]. As a result, the agreement follows the call for "green industrialization", creating both environmental and economic benefits.

Then, the GCC and non-GCC regions reduce emissions when open trade. Middle Eastern countries' economies rely heavily on oil trading. With returns from open trade, countries are actively investing in sustainable industries. In fact, Abu Dhabi operates the world's leading solar renewable energy projects. Thus, this region is becoming more and more emission-efficient. Moreover, the GCC region is less efficient at reducing emissions than non-GCC regions. One important reason is that the GCC agreement intends to enhance its global oil power. They actively signed trading agreements with other international importers including India, China, Russia, the UK, etc. Therefore, the GCC enhances significant economic opportunity and fosters oil drilling, processing, and exporting, which all result in carbon emissions. Plus, all GCC member countries are reliant on fossil fuels to generate electricity. In conclusion, GCC countries should continue to reduce carbon emissions in the region.

By ranking, SAARC has the highest estimate. The regression result indicates that SAARC is the least efficient region for carbon emission when increasing trade openness. Indeed, some main driving forces behind emissions in SAARC are rapid industrialization, urban population, and the extensive use of fossil fuels [11]. Therefore, SAARC countries, especially India and Pakistan, should control the population ratio, encourage the usage of greener technology in production, and accelerate the transition into sustainable energy.

Lastly, the regression result shows the change in effect size of EAEU, non-EAEU, MERCOSUR, non-MERCOSUR, RCEP, non-RCEP, USMCA, and non-USMCA to be not significantly different from 0.0036 (the estimate for afCFTA). The statistical insignificance may be because some of these agreements, like the RCEP, are cross-continental. There are more influential factors that Model 3 does not capture. Another explanation is that there exist other agreements that cause distractions to the analysis. However, as the effect sizes are positive, these regions still have the potential to invest in a greener economy and efficient trading.

To sum up, a few policy implications are derived from this section. Firstly, from an environmental aspect, countries that are categorized as non-EU and non-afCFTA could join the EU and afCFTA, respectively, to become more emissions-efficient. Secondly, it is critical for SAARC countries to invest in a greener economy. Additionally, EAEU, non-EAEU, MERCOSUR, non-MERCOSUR, RCEP, non-RCEP, USMCA, and non-USMCA should not lose their guard against carbon emissions. Countries should make an active effort to lower carbon transition from high-income countries, reduce fossil fuel subsidies, and increase the share of electricity generated using renewable energy sources.

6. Conclusion

More and more countries are adopting FTAs to pursue economic benefits. The resulting environmental consequences are critical in policy planning. Using panel data analysis, two regression models are built to investigate the relationship between trade openness and carbon emissions at both regional and continental levels, leading to the following conclusions.

Firstly, as trade openness increases by one percentage point, continents that will increase carbon emissions are expected to be Asia, Africa, South America, and North America. South America and Africa are the least efficient in emission control when trading. Other continents experience a negative relationship between variables. Countries on high-income continents often have an efficient trading process that produces less emissions compared to countries on low-income continents. They should cooperate to reduce emissions together, and countries from low-income continents should exert more effort into emission regulations.

At a regional level, positive relationships between carbon emission and trade openness are observed in afCFTA, non-afCFTA, SAARC, EAEU, non-EAEU, MERCOSUR, non-MERCOSUR, RCEP, non-RCEP, USMCA, and non-USMCA free trade regions. Among them, SAARC is the most inefficient in emissions control when trading. Conversely, other regions experience a negative relationship between variables. From an environmental perspective, non-EU and non-afCFTA countries should join the FTA for emission efficiency. Countries in other regions should insert additional efforts into carbon reduction.

The approach represented in this study has several downsides. Firstly, this study only considers the agreement that has the most significant trade volume, while other agreements are neglected. Thus, the omitted FTAs cause endogeneity as overlapping agreements exist between countries. Therefore, the FTA categorization is not inclusive and does create a degree of bias in estimation. Model-wise, regression models 2 and 3 only include some observed and unobserved variables related to carbon emissions. While other variables are in effect, trade openness is only partially independent from the error term. Future research should conduct more comprehensive research with the overlap of free trade agreements and more covariates considered. At the same time, this study did not verify the quadratic relationship between GDP and carbon emissions as proposed in the CKC model. Additionally, this study is limited to data from 1990 to 2019, and some data for specific countries are missing in given years. Future researchers can extend the study period and establish a more complete data set for a more inclusive analysis.

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