SPECIALISED MASTER IN INTERNATIONAL AND DEVELOPMENT ECONOMICS

What is the impact of bilateral trade on climate change in Sub-Saharan African countries?
A gravity model approach

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Award date:
2023

Awarding institution:
University of Namur

What is the impact of bilateral trade on climate change in Sub-Saharan African countries?

A gravity model approach

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Academic year 2022-23

Project presented as part of the requirements for the award of the Specialized Master in International and Development Economics Jointly organized by the ESLN and the ESL

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Acknowledgements

I would like to thank Professor Arastou KHATIBI for his support during the writing of this project. Thank you for giving me the opportunity to choose my angle of study and for encouraging me to pursue it.

I would also like to thank Professor Stéphanie WEYNANTS for her invaluable advice and encouragement.

I would like to extend special thanks to Professors Florian MAYNERIS and Julien MARTIN of the Université du Québec à Montréal for introducing me to the subject of international trade and the gravity equation.

Finally, I would like to thank all the students in the SMIDE program. Thank you for giving me so much knowledge and for always supporting me.

Abstract

This research aims to provide a comprehensive understanding of the relationship between bilateral trade and climate change in Sub-Saharan African countries. Using a gravity analysis framework for a panel of 30 countries, I analyse CO_2 emissions and natural resource depletion in relation to trade. The results show a positive correlation between bilateral trade and CO_2 emissions as well as bilateral trade and natural resources depletion, especially in the exporting country, particularly among Sub-Saharan African countries due to commodity driven exports. The study limitations include complexities in measuring resource depletion and a small sample size of 30 countries. However, our results suggest the importance of implementing climate policies in developing countries and fostering global cooperation to share sustainable practices. This research highlights the need for collective action to address the environmental impact of international trade on Sub-Saharan African countries.

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1. Introduction

The global landscape of international trade has undergone a remarkable transformation in recent decades. According to the World Trade Organization (WTO), since the creation of the General Agreement on Tariffs and Trade (GATT) in 1947, international trade has increased by 4500%, elevating trade value to 400 times their 1950 levels. (WTO | Trade Developments in the WTO Framework: Useful Statistics, 2023). While trade increases production opportunities, economic advancement, and poverty reduction, it has also sparked concerns about its environmental ramifications. As economies become more integrated with more and more free trade agreements signed between countries and so less trade barriers, the expansion of value chains has engendered an upsurge in transport flows, leading to an increase of global pollution. The simultaneous interplay of these dynamics has prompted a pressing need to comprehend the intricate relationship between trade growth and its environmental impacts.

At the same time, developing countries are becoming increasingly important on the world stage. As major exporters of commodities, they are perfectly integrated into the global value chain. While their integration into the world market allows them to experience rapid economic growth and a global improvement in well-being (Robertson et al., 2021), the effects on their environment are visible: air pollution, deforestation, water pollution. Environmental policy development is becoming a necessity.

While many studies have examined the relationship between trade openness and environmental degradation, to date, no comprehensive study has explored the intricate ties between export volumes, CO2 and natural resources depletion for Sub Saharan African countries, using a gravity equation, a gap that this present study aims to address.

This study is organized into six sections. The first section is devoted to the review of the existing literature on trade and climate change, theoretically and empirically. The second section presents the data used and the third section exposes the methodology. Then, the fourth section shows the results of the study and the analysis. Finally, the fifth section is a discussion about the limitations of my studies and the potential policy implications of the results. And section six concludes.

2. Literature review

2.1 Theoretical literature

2.1.1 Grossman and Krueger, 1991

The literature on the impact of trade openness on the environment and more specifically environmental degradation and climate change dates back to the paper of Grossman et Krueger (Grossman & Krueger, 1991), in which they set out a framework for analysing the effects of North American Free Trade Agreement (NAFTA) on the environment. They identified three distinct channels through which trade liberalization affects resources depletion and pollution. The first channel is the scale effect and predicts that the liberalization of trade will increase the total amount of pollution generated by the increase of the economic activity if they stay unchanged. Thus, the excess demand of goods will generate an excess demand of energy. If this additional energy is produced using the same polluting processes, environmental degradation will increase. The second mechanism is the composition effect, resulting from a change of countries specializations following trade openness. When trade liberalized, the country's mix production shifts toward the production of goods in which he has a comparative advantage and the impact on the environment will depend on the environmental regulations in force in each country. Thus, if a country derives its comparative advantage from a more flexible environmental policy, it will change its production mix towards more polluting goods. Consequently, the country exporting these goods could generate less domestic pollution compared to the pollution associated with the imported goods. However, if the source of the comparative advantage is the difference in productivity and factor endowments, the effect on the environment is ambiguous and depends on the polluting nature of the activity in which the country specializes. Finally, the third channel is the technical effect which makes it possible to limit the impact of opening to international trade on environmental degradation. Indeed, there are two hypotheses that could explain this phenomenon, especially for developing countries. Firstly, developing countries do not have sufficient access to less polluting technologies either because their domestic companies do not produce them in sufficient quantities or because the price is too high. Opening to trade would allow them to benefit from these new, less polluting techniques at lower cost. Secondly, international trade would increase the wealth of exporting countries and because of this growth, the authorities would demand a better environment. Thus, policies that counteract environmental degradation are likely to be put in place. Finally, as the composition effect is not determined and the other two effects conflict, the overall impact of international trade on the environment will depend on the strength of each channel (*WTO | Trade and Environment, 2023*).

2.1.2 Environmental Kuznet Curve

Following this work, in 1995, Krueger and Grossman introduced the environmental Kuznet Curve that depicts the inverted U-shaped relationship between economic growth and environmental degradations. In the first phase, as a country develops and grows, the damage to the environment increases. Indeed, during the expansion phase of an economy, often characterised by the opening up to international trade, pollution and resource degradation take place. But then a certain level of per capita income is achieved, estimated by Krueger and Grossman at US$ 8000. According to this turning point, the level of income is sufficient to be reinvested in environmental preservation. Their results show that the hypothesis of economic growth deteriorating the environment is rejected at a 5% significance level when the country exceeds $10,000 per capita income. As we can see on figure 1, before this turning point and as GDP per capita increases, environmental degradations increases and after this turning point, income level is sufficient enough to be reinvested in less polluting production processes and depollution activities, leading to a decreases of the overall environment degradation.

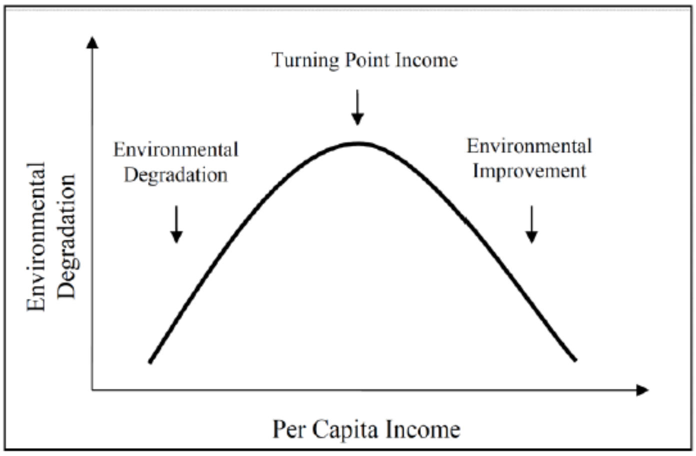

Figure 1 : Environmental Cuznet Curve

Source : Yandle, Bhattarai and Vijayaraghavan, (2004)

2.1.3 The Heckscher-Ohlin model and the Stolper-Samuelson theorem

If we consider the theoretical framework of the Heckscher-Ohlin model, a country's openness to international trade leads it to specialise and export the good using the factor it is relatively best endowed with and to import the other (Mayneris, 2021a). If we assume that developing countries are relatively abundantly endowed with environmental factors, the opening of these countries to trade would lead to their specialisation in the production of goods using environmental factors relatively abundantly. Thus, the environmental degradation of developing countries increases. However, if we consider the Stolper-Samuelson theorem, which states that the increase in the relative price of a good increases the remuneration of the factor used relatively intensively in the production of this good and decreases the remuneration of the other factor, the price for the use of goods using environmental factors intensively will increase (Mayneris, 2021a). This will lead to the adoption of production techniques that are less polluting and detrimental for the environment (Dean, 2002).

2.2 Empirical literature

2.2.1 Negative relationship between trade and climate change

Following these theoretical foundations, many researchers have investigated the link between trade openness and environmental degradation, but the results remain controversial. For example, some papers have found that international trade is beneficial to the environment. Antweiler et al (2001), for example, used cross-country time series data from over 40 developed and developing countries. By decomposing the SO2 data into scale, technique and composition effects described on the paper of Grossman and Krueger in 1991 (see 2.1), they found that international trade liberalisation is good for the environment. Indeed, they first estimated that the composition effect implies that increased international trade leads to a slight increase in pollution levels. The technical and scaling component estimates show, however, that the SO2 concentration decreases by 1% when the output and income generated by an increase in international trade increase by 1%. Combining these three effects, they show that trade openness decreases pollution in terms of SO2 emissions. Frankel and Rose (2005) found similar results for the effect of international trade on SO2 emissions. They estimated a cross-country equation with a measure of environmental damages as the dependent variable. They found that openness to international trade is not detrimental to the environment. In other words, when a country opens to trade, SO2 and NO2 emissions decrease significantly. They also reject the null hypothesis that developing countries would specialize in the production of environmentally damaging goods.

2.2.2 Positive relationship between trade and climate change

In contrast to these results, other papers have found a negative link between openness to international trade and the environment. Thus, Feridun et al (2006) started from the observation that, despite theoretical predictions, we observe negative effects of trade on the environment, despite the diffusion of more nature-friendly production technologies. To address this, they constructed a model that decomposes the effect of trade on the environment into three effects, as outlined by Grossman and Krueger (1991); scale, composition and technique effect and analysed the results for Nigeria. They found that international trade has overall negative effects on the environment in terms of CO2 emissions and deforestation. Indeed, the scale and technique effect are detrimental to the environment. Only the composition effect on the use of natural resources is beneficial to the environment. But the total effect is negative.

Aklin (2016) also demonstrates a similar relationship between trade and environment. He constructed a database of 151 countries for a period from 1950 to 2000 and estimates a spatial regression model of CO2 emissions. He finds nuanced results depending on the level of development of countries. Thus, the environment of low-income countries is more affected by international trade because these countries prioritise their development and are therefore less concerned about the additional pollution caused by the increase in production due to the opening to trade. But for high-income countries, the environmental impact of international trade is beneficial because it encourages countries to move towards greener and more environmentally friendly processes. Aklin argues that the negative environmental effects of low- and middle-income countries could be reduced if pollution emitted as a whole, not just local pollution, is considered, and if the diffusion of more environmentally friendly technologies is facilitated. Furthermore, the results highlight the divergence of impacts depending on the type of pollution considered. For example, air pollution may increase locally because of trade, but greenhouse gas emissions may decrease through the introduction of greener technologies.

2.2.3 Mixed results on the relationship between trade and the environment

A part of the literature on this topic relates to papers that provide mixed results on the impact of openness to international trade on environmental degradation. This is the case of the paper by Yao et al (2019) who studies the impact of free trade agreements on environmental sustainability. Using a gravity model to determine which country exports pollution to which other country, they determine a positive relationship between international trade and bilateral CO2 emissions, with a nuance depending on the level of development of countries. Thus, for high-income countries, free trade agreements are beneficial for the environment. Countries with higher environmental regulations are more likely to sign free trade agreements with countries with similar regulations, thus promoting a virtuous circle. However, for low- and middle-income countries, free trade agreements worsen environmental degradation because they have too flexible pollution standards.

Kim and al. (2019) achieve similar results by studying a sample of 131 developed and developing countries for a period from 1960 to 2013. They found that when developing countries trade with developed countries, the impact on their environment is detrimental. When developing countries trade with each other, the effect on their environment is mixed and depend on the level of pollution in the destination country. But when developed countries trade, either with each other or with developing countries, CO2 emissions decrease. One reason for these findings, put forward by the authors, is that developing countries mostly export energy-intensive goods and are therefore large emitters of CO2. Thus, regulations to limit the impact of international trade on the environment must consider the countries of origin and destination as well as the nature of the exported products.

2.2.4 Policy implications

Finally, some empirical works study the impact of trade on the environment to make public and trade policy recommendations to developed and developing countries and international institutions. For example, Shapiro (2016) examined the relationship between trade-related costs, CO2 emissions and the environment. He uses data from 128 countries for the year 2007 and for 13 trade sectors and one non-trade sector. He finds that reducing trade costs has adverse effects on the environment. Thus, policymakers need to design trade policies carefully.

Another study by Longe et al (2020) highlight the urgency for African countries and international organisations to respond to the adverse impact of international trade in Africa. Indeed, the authors determine that the rapid growth of trade has led to multiple forms of pollution for African countries: air pollution, water pollution, deforestation, and biodiversity loss. The authors also point to three causes of the lack of capacity of African countries to respond to these challenges: lack of environmental regulations, weak institutions, and insufficient financial resources.

2.3 Literature gap

In summary, the literature on the impact of trade openness on the environment is extensive and reveals complex relationships. Early works by Grossman and Krueger (1991) laid the groundwork by introducing the various channels through which trade liberalization could influence environmental degradation, including scale, composition, and technical effects. The subsequent introduction of the environmental Kuznet Curve by Krueger and Grossman (1995) added a dimension of economic growth's interaction with environmental preservation.

Theoretical foundations, such as the Heckscher-Ohlin model and the Stolper-Samuelson theorem, have provided insights into how openness to trade can lead to specialization, potentially affecting environmental outcomes. However, as our discussion has shown, empirical findings have often yielded mixed results. Some studies, like those by Antweiler et al. (2001) and Frankel and Rose (2005), suggest that trade liberalization can be beneficial for the environment, while others, like Feridun et al. (2006) and Aklin (2016), highlight potential negative consequences. Furthermore, studies by Yao and al. (2019) or Kim and al. (2019) demonstrates mixed results by demonstrating how trade agreements and technology diffusion impact trade positively or negatively, depending on factors such as income levels and emission types.

As we move forward, addressing the environmental challenges posed by international trade requires nuanced policy considerations. Shapiro (2016) examination of trade-related costs and Longe and al.(2020) investigation of trade's effects on African countries underscore the urgency for targeted policies that account for the varying contexts and challenges faced by different economies.

Finally, some studies address the environmental challenges that requires a policy consideration. Shapiro (2016) and Longe and al. (2020) underscore the urgency for targeted policies that account for environmental degradations.

In the following sections, I aim to contribute to this literature by exploring the specific relationship between bilateral trade, CO2 emissions and natural resources depletion in Sub-Saharan African countries and how trade with developed countries affect CO2 emissions and natural resources depletion, using a gravity equation. By this analysis, I hope to deepen my understanding of how trade dynamics interact with environmental concerns. With my research, I will try to provide insights that can guide policy decisions toward more sustainable trade practices, while considering the characteristics of Sub-Saharan African countries.

3. Data

I use 3 databases to estimate the impact of trade openness on climate changes. The first one is the CEPII gravity database of 2022. This database provides information on trade flows as well as geographic, cultural, trade facilitation and macroeconomic variables for 252 countries or territories. Data is available from 1948 to 2019 and each observation corresponds to a pair of countries, meaning a combination of an exporting country, an importing country, and a year. The two other databases used come from the World Bank (2023). The first one provides information on CO_2 emissions in metric tons per capita for 210 countries or territories, from 1990 to 2019. The second one provides information on natural resources depletion as a percentage of GNI for 203 countries or territories, from 1970 to 2020. Considering the availability of data in the various databases and for the selected countries, I have selected the study period from 1990 to 2019.

Depending on data availability and my study interests, I selected 30 countries described on table X: 15 Sub-Saharan African countries (countries 1 to 15) and 15 developed countries (countries 16 to 30). Developed countries selected are chosen among high income countries defined by the income group classification of the World Bank. Each year, the World Bank uses gross national income per capita in US dollars to classify countries into four income groups: low, lower-middle, upper middle- and high-income countries (*WDI - the World by Income and Region*, 2023). The 15 Sub-Saharan African countries are all low or lower middle-income countries, except for South Africa which is an upper middle-income country. All 15 developed countries are high income countries. Table X also shows the results for each country in terms of average CO_2 emissions in metric tons per capita and average resource depletion in percentage of GNI for the period 1990-2019.

Table 1 : List of countries

Num	Country	Average CO2 emissions (metric ton of capita)	Average resources depletion (% of GNI)
1	Benin	0.33	3.83
2	Botswana	2.27	1.79
3	Burkina Faso	0.11	0.94
4	Burundi	0.03	18.26
5	Cameroon	0.36	7.05
6	Ethiopia	0.08	16.62
7	Ghana	0.37	9.39
8	Kenya	0.28	3.98
9	Madagascar	0.1	5.21
10	Mauritania	0.61	3.52
11	Niger	0.07	0.41
12	Rwanda	0.07	6.28
13	South Africa	7.11	2.77
14	Togo	0.27	7.33
15	Zambia	0.25	7.33
16	Belgium	10.13	0.02
17	Canada	15.92	1.75
18	China	4.55	3.25
19	Denmark	9.34	0.63
20	France	5.62	0.05
21	Germany	9.94	0.11
22	Italy	6.94	0.07
23	Japan	9.23	0.007
24	Netherlands	9.95	0.46
25	Portugal	5.13	0.19
26	Singapore	9.17	0.0007
27	Spain	6.3	0.03
28	Sweden	5.42	0.08
29	United Kingdom	8.16	0.81
30	United States of America	18.15	0.77

Table 2 shows descriptives statistics of the variables I use for this study. I use 9 variables: 6 continuous variables and 3 binary variables. The first variable of interest is tradeflow, taken from the CEPII database and presents the trade flow for each pair of exporter-importer-year in thousands current $US (Conte et al., 2022). On average, the tradeflow is 5,078,515 thousand $US. The standard deviation which measures the spread of observations around the mean is quite high, around 2 million thousand $US. The second variable of interest is the natural resource depletion taken from the World Bank database and is computed as the sum of net forest depletion, energy depletion including coal, crude oil and natural gas and mineral depletion (tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite and phosphate) and is expressed as a percentage of GNI for each country. (*Glossary | DataBank*, 2023). The average rate of depletion is 3.94% of GNI for the sample, with a maximum rate of 41.41% of GNI. The third variable of interest is the carbon dioxide emissions taken from the World Bank and is expressed in metric tons per capita (*Glossary | DataBank*, 2023b). The average value of carbon dioxide emissions is 4.88 metric tons per capita for the whole sample with a minimum of 0.02 and a maximum emission of 20.47 metric tons per capita. Other variables are control variables taken from the CEPII database. Population, gdpcap and dist are unilateral variables that shows respectively the population in thousands, the GDP per capita in current thousands $US and the distance in kilometres between the most populated city of each country (Conte et al.,2022). The three last variables are binary bilateral variables. The contig variable is 1 if countries share a common border. The comlang_off variable is 1 if countries share a common official or primary language and the col_dep_ever variable is 1 if countries was ever in a colonial or dependency relationship before 1948.

Table 2 : Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
depletion	30688	3.943	6.417	0	41.412
CO2	30720	4.884	5.061	.02	20.47
tradeflow	19547	5078515	20677668	.001	5.009e+08
pop	28800	79944.208	231741.64	1383.912	1407745
gdpcap	28736	16.686	18.633	.108	66.859
dist	27000	5816.925	3670.642	10	15347
contig	.	.	.	.	.
0	27000	.953	.211	0	1
1	27000	.047	.211	0	1
comlang off	.	.	.	.	.
0	27000	.729	.445	0	1
1	27000	.271	.445	0	1
col dep ever	.	.	.	.	.
0	27000	.953	.211	0	1
1	27000	.047	.211	0	1

4. Methodology

4.1 The basic gravity equation

The gravity equation measures how much two countries should trade given their respective economic weights, approximated by their GDPs, trade costs, approximated by distance, and other trade cost determinants denoting privileged relations between two countries (colonial past, common border, common language, etc.) (Mayneris, 2021b). The gravity equation was first used by Tinbergen (1962) to study bilateral trade flows. Despite its initial criticism for lacking economic foundations, the model has been taken up and improved by other trade economists such as Anderson (1979) and Anderson and Van Wincoop (2003).

The basic gravity equation of trade can be written as the following:

$$\ln x_{ij} = \delta_0 \ln GDP_i + \delta_1 \ln GDP_j + \delta_2 \ln Dist_{ij} + \delta_3 \ln contig_{ij} + \delta_4 \ln com\_lang_{ij} + \delta_5 \ln colony_{ij} + \cdots + \varepsilon_{ij} \quad (1)$$

With x_{ij} showing value exported from country i to country j, GDP showing the nominal GDP of country i then country j, Dist showing the distance in kilometers between country i and country j. Then, contig, com_land and colony are dummies variables that are equal to 1 if respectively countries share a common border, a common language or were ever in a colonial relationship. Other control variables can be added to the equation.

This basic gravity equation relays on two principles: bigger countries trade more, and closer countries trade more (Shepherd, 2016) and this can be applied to all countries (developed and developing countries) as well as all types of tradable products. However, this basic model faces difficulties to estimates trade between countries when parameters change. For example, the basic equation doesn't allow for a change in trade costs between countries. Another example is when transport costs decrease everywhere, including within countries due to a decrease in the price of oil. The basic model of gravity would predict a proportional increase in trade across all countries including the domestic trade. But relative prices have not change so the consumptions pattern would stay constant (Shepherd, 2016). That is why the basic model has evolved over time to reflect more accurately economic reality and basic equation was replaced by the structural one.

Another problem with the naïve gravity equation is the presence of endogeneity. The literature on the subject suggests that the use of structural gravity is better over the use of naïve gravity. For example, Anderson and Van Wincoop (2003), Baier and Bergstrand (2009) and Head and al. (2010) highlight the endogeneity problem using the naïve gravity equation and that the use of structural gravity equation allows to reduce this concern. In this situation, one or more independent variables in the regression model are correlated with the error term, which causes biased estimations. Coefficients are then over-or-under estimated, and the causal relationship cannot be assessed (Wooldridge, 2010). In the context of gravity equation, endogeneity can arise from 4 types of causes (Hill et al., 2020):

1. Omitted variables: there is a bias when some relevant variables are omitted on the model and are correlated with the dependent variable or the independent variables.
2. Simultaneity: there is a bias when variables of the regression model are jointly determined by each other.
3. Measurement error: there is a bias when the error of measurement of an independent variable is correlated with the dependent variable.
4. Selection: there is a selection bias when the selection into sample is not random.

To face the endogeneity problem, I am going to develop the structural gravity model of bilateral trade.

4.2 The structural gravity model

To solve issues of the naive basic gravity model raised in the previous section, a structural gravity model was introduced in the economic literature with Anderson (1979), Anderson and Van Wincoop (2003) or Head and Mayer (2014). In this section, I will detail the model of Head and Mayer that considers multilateral resistance terms that measures the size of exporters and importers in real terms, for given nominal values of output and expenditure. Multilateral resistance terms are factors that affect trade flows between all pair of countries in a multilateral setting. These terms are introduced to address the potential endogeneity biais described on the previous section. Multilateral resistance terms help to address this issue by considering the trade relationships of a country with all its trading partners simultaneously. These terms capture the broader trading environment and provide a way to account for the influence of third-party countries on bilateral trade (Mayneris, 2021b).

This structural gravity equation has the following form:

$$X_{ij} = \frac{Y_i}{\Omega_i}\frac{X_j}{\Phi_j}\phi_{ij} \qquad (2)$$

Where $Y_i = \sum_j X_{ij}$ is the nominal value of exporter's production.

$X_j = \sum_i X_{ij}$ is the importer's total nominal expenditure.

ϕ_{ij} is a measure of the degree of freedom to trade between i and j (which is inversely related to trade costs) and measure the resistance faced by the country in trading with other countries.

Ω_i and Ω_i are the multilateral resistance terms that makes it possible to measure the size of exporters and importers in real terms for given nominal values of output and expenditure and ensure that the estimation is not biased by various factors affecting the degree of competition between them.

$$\Omega_i = \sum_l \frac{\phi_{il} X_l}{\phi_l} = \sum_l \phi_{il} M_l \qquad (3)$$

$$\phi_j = \sum_l \frac{\phi_{lj} Y_l}{\Omega_l} = \sum_l \phi_{lj} S_l$$

With *l* representing all trading partners.

Whereas the naive form of the gravity equation suggested using the logarithm of GDP as proxies for exporters' ability to beg at all destinations and the characteristics of destination markets, the structural equation suggests using fixed effects (Head & Mayer, 2014). Harrigan (1996) was the first to use importer-exporter fixed effects. The advantage of fixed effects is that they provide an estimate of the consistency of the equation's components, as well as controlling for unobservable characteristics that would shift a country's overall level of imports or exports. For example, a large proportion of Europe's imports pass through the port of Antwerp, artificially inflating Belgium's imports. The use of fixed effects solves this problem (Head & Mayer, 2014).

4.3 Empirical strategy

To study the impact of climate change on international trade, I decided to estimate a gravity equation described in equation 4. My dependent variable is bilateral trade flows. I have included 7 independent variables: the GDP per capita of each of the two countries, the distance between the two countries, a dummy variable equals to 1 if the countries share a common border, a dummy variable equals to 1 if the countries share a common official or main language, a dummy variable equals 1 if the countries were ever in a colonial relationship before 1948, the CO2 emissions for each country and the natural resources depletion of each country.

$$\ln x_{ij} = \alpha_0 \ln GDP_i + \alpha_1 \ln GDP_j + \alpha_2 \ln Dist_{ij} + \alpha_3 \ln contig + \alpha_4 \ln com\_lang_{ij} + \alpha_5 \ln colony_{ij} + \alpha_6 \ln CO2_i + \alpha_7 \ln CO2_j + \alpha_8\, depletion_i + \alpha_9\, depletion_j + \varepsilon_{ij} \qquad (4)$$

First, I'll estimate this equation naively, i.e. simply by OLS. Then, I'll estimate it using its structural form, and add year fixed effects and country fixed effects. This will enable me to compare the two models and perform a Haussman test to determine which model is preferable in my research.

Finally, I will re-estimate this X equation by conducting subgroup analysis to have a better comprehension of the subject. For the first subgroup analysis, I will run the regression only for Sub-Saharan African countries (SSA) and estimate the coefficients of the regression when they trade among each other. I will then perform the same regression for developed countries. Finally, I will finish my analysis by estimating the 4^{th} equation when SSA countries are exporters and developed countries importers and the opposite specification. This will allow me to study the situation when SSA countries trade only with developed countries and not among them.

5. Results

This section presents the outcomes of our analysis using the methodology described on section 4.3. Note that in the tables presented in this section, "exp" refers to exporter and "imp" refers to importers.

5.1 Naïve gravity equation

Table 3 shows results of the estimation of the naïve gravity equation to investigate the determinants of bilateral trade flows. I estimate three different specifications of the equation, incorporating key control variables including CO2 emissions and natural resources depletion, to unravel their potential impacts on trade relationships. The dependent variable of the equation is the logarithm of bilateral trade flows.

In the first specification, in addition to the classic control variables for gravity equations, such as distance, demography or the existence of a potential colonial relationship, I have only introduced CO2 emissions for exporting and importing countries. All coefficients of that specification are significant except for the language variable and the constant. Coefficients of CO2 emissions are significative and positive for both exporting and importing countries. The results report that when CO2 emissions for the exporting country increases by 1 percent, the bilateral trade flow increases by 0.7 percents. For importing country, bilateral trade flow increases by 0.51 percent.

The second specification introduces natural resources depletion as control variable. The effect is higher for importing countries. When natural resources depletion increases by 1 percent in the importing country, bilateral trade flow decreases by 0.07 percent, whereas it decreases by only 0.003 percent for the exporting country. But the effect is higher when both CO2 emissions and natural resources depletion are added as control variables (specification 3). While the effect on CO2 emissions remains broadly similar for specification 3, the effect of resource depletion for exporting countries is much greater. Indeed, this effect increases from a reduction in bilateral trade of 0.0003% to 0.02%. From this table, we also notice that the R-squared is higher for the third specification, representing a higher fit of the model, with 82.6 percent of the variability of the dependent variable is explained by the independent variables

Table 3: Estimation of the naïve gravity equation

Dependent variable: Logarithm of bilateral trade flows

VARIABLES	(1) CO2	(2) Depletion	(3) CO2 and Depletion
Log(distance)	-1.055***	-0.955***	-1.079***
	(0.0168)	(0.0173)	(0.0166)
Log(population_exp)	0.925***	1.029***	0.931***
	(0.0119)	(0.0108)	(0.0119)
Log(population_imp)	0.788***	0.881***	0.807***
	(0.0107)	(0.0101)	(0.0106)
Log(GDP/capita_exp)	0.570***	1.199***	0.545***
	(0.0223)	(0.00874)	(0.0239)
Log(GDP/capita_imp)	0.450***	0.846***	0.341***
	(0.0207)	(0.00863)	(0.0221)
Contiguous	1.273***	1.405***	1.145***
	(0.0698)	(0.0734)	(0.0690)
Language	0.0446	0.0952***	0.0879***
	(0.0340)	(0.0354)	(0.0339)
Colony	1.154***	0.963***	1.151***
	(0.0473)	(0.0483)	(0.0476)
Log(CO2_exp)	0.699***		0.709***
	(0.0244)		(0.0245)
Log(CO2_imp)	0.510***		0.548***
	(0.0222)		(0.0223)
Log(depletion_exp)		-0.000344	-0.0197***
		(0.00607)	(0.00612)
Log(depletion_imp)		-0.0707***	-0.0857***
		(0.00598)	(0.00576)
Constant	-0.0509	-3.658***	-0.0391
	(0.218)	(0.198)	(0.217)
Observations	19,547	19,489	19,489
R-squared	0.824	0.812	0.826

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.2 Structural gravity equation

Table 4 reports result of the structural gravity equation described on point 4.2. This table reports 3 specifications, the same as the table 3 but it includes country and year fixed effects. All coefficients reported are statistically significant. The population variable is interesting to look at because the regression reports that there is a negative correlation between population of the exported country and bilateral trade whereas there is a positive relationship between population of the imported country and bilateral trade. According to the third specification, when the population of the exported country increases by 1 percent, the bilateral trade decreases by 0.67 percent. But when the population of the imported country increases by 1 percent, bilateral trade decreases by 0.64 percent.

There are several hypotheses on why there is a negative correlation between the size of the population of the exporter and bilateral trade. The first hypothesis focuses on the domestic consumption. As the population of the exporter country increases, the domestic demand for goods increases, so there is a higher demand for the production on the domestic market, resulting in fewer goods available for export. The second hypothesis relies on income inequality. As the population of the exporter country increases and a significant part of the population has low disposable income, the demand for imported goods might be limited, leading to a decrease in bilateral trade.

This table also reports positive and significative correlation between CO2 emissions and bilateral trade and natural resources depletion and bilateral trade, both for importers and exporters, meaning that higher trade flow is associated with higher environmental degradations both in the exporter and the importer country.

Table 4: Estimation of the structural gravity equation

Dependent variable: Logarithm of bilateral trade flows			
	(1)	(2)	(3)
VARIABLES	CO2	Depletion	CO2 and Depletion
Log(distance)	-1.237***	-1.241***	-1.240***
	(0.0720)	(0.0719)	(0.0720)
Log(population_exp)	-0.687***	-0.426*	-0.673***
	(0.215)	(0.217)	(0.212)
Log(population_imp)	0.631***	0.756***	0.645***
	(0.221)	(0.199)	(0.221)
Log(GDP/capita_exp)	0.648***	0.695***	0.646***
	(0.0737)	(0.0632)	(0.0730)
Log(GDP/capita_imp)	0.711***	0.690***	0.704***
	(0.0746)	(0.0747)	(0.0741)
Log(CO2_exp)	0.397***		0.386***
	(0.0994)		(0.0981)
Log(CO2_imp)	0.266***		0.257***
	(0.0957)		(0.0951)
Log(depletion_exp)		0.0416**	0.0408**
		(0.0162)	(0.0160)
Log(depletion_imp)		0.0349***	0.0350***
		(0.0112)	(0.0110)
Constant	19.21***	15.70***	19.06***
	(2.505)	(2.436)	(2.520)
Observations	19,547	19,489	19,489
R-squared	0.857	0.856	0.857
Country FE	YES	YES	YES
Year FE	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.3 Comparing naïve and structural gravity equation

Table 5 reports and compares results of the naïve and the structural gravity equation. Both specifications include the same control variables, but the second specification includes country and year fixed effects. Whereas tables 3 and 4 show that the specification with both CO2 emissions and natural resources depletion as control variables seem to be preferred for the higher explanation of the variability of bilateral trade flow, this table compares the model with and without country and year fixed effects.

We notice that all variables are statistically significant but the variables population for the exported countries and both depletion variables change signs. The first specification reports that an increase of the natural resources depletion both for exporters and importers implies a decrease of the bilateral trade flows while the second specification implies an increase in the bilateral trade flows.

We also notice that naïve gravity equation seems to overestimate the impact of CO_2 emissions compared to the structural form of the gravity equation. Whereas the naïve equation reports that an increase of 1 percent of CO_2 emissions in the exporter country increases bilateral trade flows by 0.7 percent, the structural form predicts that bilateral trade flow only increases by 0.38 percent.

Now that we have identified the differences between the estimates of the two specifications, we ask ourselves which model is better, naive gravity or structural gravity? As we saw on section 4.1, we suspect that the naïve gravity equation has endogeneity. So I decide to perform a Hausman statistical test to determine whether the estimator of the naive gravity equation is consistent and unbiased in the presence of endogeneity. The null hypothesis of this test is that the estimator of the naive gravity equation is consistent and unbiased even in the presence of endogeneity, and that this estimator is not systematically different from the estimator of the structural gravity equation. The Hausman test yields a chi2 of 1203.82 and a p-value of 0.0000. I therefore reject the null hypothesis that the random effects are independent, suggesting that the structural gravity model with fixed effects is preferable.

Thus, considering the theoretical and empirical justifications and the Hausman test, I conclude that it is preferable to use the structural gravity equation with fixed effects in order to avoid a potential endogeneity problem.

Table 5: Comparison of the estimation of the gravity equation with and without FE

Dependent variable: Logarithm of bilateral trade flows

VARIABLES	(1) Without FE	(2) With FE
ldist	-1.226***	-1.240***
	(0.0140)	(0.0720)
lpop_exp	0.946***	-0.673***
	(0.0119)	(0.212)
lpop_imp	0.822***	0.645***
	(0.0107)	(0.221)
lgdpcap_exp	0.548***	0.646***
	(0.0240)	(0.0730)
lgdpcap_imp	0.343***	0.704***
	(0.0225)	(0.0741)
lCO2_exp	0.707***	0.386***
	(0.0249)	(0.0981)
lCO2_imp	0.546***	0.257***
	(0.0227)	(0.0951)
ldepletion_exp	-0.0241***	0.0408**
	(0.00625)	(0.0160)
ldepletion_imp	-0.0901***	0.0350***
	(0.00591)	(0.0110)
Constant	1.019***	19.06***
	(0.206)	(2.520)
Observations	19,489	19,489
R-squared	0.819	0.857
Country FE	NO	YES
Year FE	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.4 Trade among developing countries VS trade among developed countries

Table 6 reports results of the estimation of the structural gravity equation both the 15 developed and the 15 SSA countries (see table 1). This table reports results when developed countries trade together, and when SSA countries trade together. All coefficients of both regressions are statistically significant except for the coefficient of the GDP per capita when the SSA county is an exporter.

We notice that distance is a greater barrier to trade for SSA countries because when the distance increases by 1 percent, bilateral trade for SSA countries decreases by 2.15 percent, against 0.87 percent for developed countries. A hypothesis for this result is the greater presence of trade agreements between developed countries. We observe a similar result for the population of both exporting and importing countries. An increase in population is more likely to increase trade in SSA countries than in developed countries.

Finally, when we look at the two climate change variables, we notice that while the coefficients of the depletion and CO2 emissions variables for importing countries are substantially identical between developed and SSA countries, the results are quite different for importing countries. For example, when CO2 emissions in SSA countries rise by 1 percent, bilateral trade increases by 1.17%, compared with only 0.25% for developed countries. And when natural resources depletion rises by 1 percent, bilateral trade between SSA and developed countries increases by 0.13% and decreases by 0.06% respectively.

4 hypotheses could explain these differences on climate change variables observed on table X between SSA and developed countries. The first hypothesis is that SSA and developed countries have different economic structures. Indeed, SSA countries rely more on resource-intensive industries while developed countries have shifted towards more diverse and cleaner industries to mitigate the impact of environmental factors on trade (Dasgupta and al., 2002). The second hypothesis is that developing countries might have a comparative advantage in industries that are more polluting or resource-intensive which explain the greater impact on CO2 emissions and natural resources depletion, compared to developed countries that are more specialized in cleaner industries (Grossman & Krueger, 1995). The third hypothesis rely on environmental regulations. Indeed, developed countries have adopted more stringent environmental regulations to mitigate their negative impact on the environment and help protect it. This might result in less CO2 emissions and more natural resources preservations compared to SSA countries where environmental regulations are less strict, resulting in a higher exploitation of natural resources and higher CO2 emissions (Cole & Elliott, 2003). Finally, the last hypothesis relies on production processes. Developed countries might have more advanced and cleaner technology that prevent environmental degradations and help them reduce CO2 emissions while SSA countries have limited access to these technologies (Bretschger & Smulders, 2006).

Table 6: Estimation of the gravity equation for developed and developing countries

Dependent variable: Logarithm of bilateral trade flows

VARIABLES	Developed	SSA
Log(distance)	-0.870***	-2.151***
	(0.0119)	(0.0358)
Log(population_exp)	0.770***	1.207***
	(0.00827)	(0.0247)
Log(population_imp)	0.753***	1.024***
	(0.00788)	(0.0192)
Log(GDP/capita_exp)	0.415***	-0.0771
	(0.0183)	(0.0517)
Log(GDP/capita_imp)	0.480***	0.515***
	(0.0159)	(0.0374)
Log(CO2_exp)	0.252***	1.172***
	(0.0289)	(0.0376)
Log(CO2_imp)	0.472***	0.593***
	(0.0159)	(0.0385)
Log(depletion_exp)	-0.0563***	0.137***
	(0.00443)	(0.0106)
Log(depletion_imp)	-0.0338***	-0.151***
	(0.00418)	(0.00987)
Observations	10,302	9,187
R-squared	0.898	0.629
Country FE	YES	YES
Year FE	YES	YES

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.5 Trade between developed and developing countries

Table 7 reports results of the regression of structural gravity equation for two specifications: (1) when SSA countries are exporters and developed countries are importers and (2) when SSA countries are importers and developed are exporters. The difference with table 6 is that in this specification, we study trade between developed and SSA countries (trade among them is excluded) but in table 6, developed and SSA countries trade among them.

We notice that some variables are not statistically significant, but we can still derive some interesting results. When SSA countries are exporters, the model predicts that an increase of 1 percent in natural resources depletion in SSA country is associated with an increase of 0.2 percent of bilateral trade flows with developed countries. As coefficients are not statistically significant, we cannot conclude anything about the impact of CO2 emissions on bilateral trade.

Table 7 : Estimation of the gravity equation for trade between developed and developing countries

Dependent variable: Logarithm of bilateral trade flows

VARIABLES	(1) SSA exporter	(2) SSA importer
Log(distance)	-10.14	-2.234**
	(10.92)	(0.761)
Log(population_exp)	-1.132	-1.106*
	(1.270)	(0.582)
Log(population_imp)	0.629	-0.381
	(13.23)	(0.620)
Log(GDP/capita_exp)	0.673**	0.895***
	(0.236)	(0.146)
Log(GDP/capita_imp)	1.588	0.612***
	(2.433)	(0.100)
Log(CO2_exp)	0.228	0.121
	(0.319)	(0.283)
Log(CO2_imp)	-0.902	0.333
	(2.082)	(0.342)
Log(depletion_exp)	0.224***	-0.00792
	(0.0561)	(0.0296)
Log(depletion_imp)	0.134*	0.0266
	(0.0740)	(0.0364)
Constant	103.8	45.37***
	(143.8)	(15.08)
Observations	356	358
R-squared	0.883	0.968
Country FE	YES	YES
Year FE	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6. Discussion

The aim of this study is to better understand the impact of bilateral trade on climate change in Sub Saharan African countries. Climate change is measured by two variables: CO2 emissions as metric tons per capita and natural resources depletion as a percentage of GNI.

The gravity analysis of bilateral trade and climate change has revealed that bilateral trade is associated with higher CO2 emissions and greater natural resources depletion rate in both developed and SSA countries. Results also report that the impact on the environment is higher for the exporter country, especially for Sub-Saharan African countries. This effect is due to the high share of commodities in SSA countries exports. Although my results corroborate the findings of some papers in the literature, my research has certain limitations.

Firstly, data on natural resource depletion is difficult to estimate and has its limitations. For example, net forest depletion only takes into account the value of timbers and does not take into account the loss of nontimber forest benefits. For mineral and energy depletion, marginal cost should be used to represent the opportunity cost of extraction, but to simplify calculations, average extraction cost is used to approximate the opportunity cost of extraction. Finally, differences in national accounts methodologies can lead to differences in the values used to measure depletion energy (*Glossary | DataBank*, 2023).

Then, for the sake of simplicity, I used a sample of 30 countries, 15 developed and 15 sub-Saharan African, but it would have been preferable to use a larger sample to represent global bilateral trade and understand all its specificities more accurately. In addition, my research period runs from 1990 to 2019 for reasons of data availability, but a wider study period would have enabled a more in-depth study of the evolution of bilateral trade and its impact on climate change.

As far as my results are concerned, they corroborate some of the literature. For example, my findings on the impact of bilateral trade on climate change are similar to those of Yao et al. (2019) concerning the positive link between international trade and bilateral CO2 emissions, depending on countries level of development. Indeed, my results highlight the fact that when Sub-Saharan African countries, being low- or middle-income countries, are more affected climatically by bilateral trade, especially when they export. For example, when Sub-Saharan African countries export goods to developed countries, natural resources depletion increases more strongly than in developed countries. The same applies to CO2 emissions, which are much higher when SSA countries trade with each other, compared with CO_2 emissions when developed countries trade with each other.

One possible explanation for this phenomenon is the lack of strict environmental regulations in SSA countries. Indeed, developed countries have stricter environmental policies, which encourage them to adopt more cautious behaviour towards polluting activities, and to adopt technologies and new processes that limit their impact on the environment. As these policies are less present and less restrictive in Sub-Saharan Africa, there are fewer incentives to turn to and invest in more environmentally friendly processes.

Based on my findings, I propose several key policy recommendations. Firstly, encouraging SSA countries to implement more restrictive climate policies would help reduce the impact of international trade on environmental degradation. Strengthening global environmental diplomacy to tackle the problem of pollution on a global scale and encourage more advanced countries to share their technologies and knowledge of less polluting production processes would also be beneficial for the reduction of pollution. Climate change must be seen as a global problem, where everyone is encouraged to make their own contribution to the global effort to reduce emissions. In addition, strengthening South-South cooperation would enable SSA countries to play a greater role in climate negotiations, and to share knowledge and processes that are more respectful of the environment.

In conclusion, my study underscores the intricate relationship between bilateral trade and climate change. While certain limitations constrain the analysis, my findings align with existing literature and offer novel insights. To respond to the challenges posed by climate change, it is imperative to adopt stricter environmental policies, encourage global collaboration and empower SSA countries through knowledge-sharing initiatives. Climate change is a global issue that necessitates collective efforts to forge a sustainable path forward.

7. Conclusion

This study analyses the impact of bilateral trade on climate change and more precisely natural resources depletion and CO_2 emissions comparing 15 Sub-Saharan African countries and 15 SSA countries, from 1990 to 2019. I use a gravity regression with country and year fixed effects, as well as several specifications to understand the dynamics of bilateral trade flows and climate change.

My results show that the use of a structural gravity equation is preferred to the naïve form of it to avoid endogeneity problems. Structural gravity equation estimates that there is a positive and significative relationship between CO_2 emissions and bilateral trade flows, as well as a positive and significative relationship between natural resources depletion and bilateral trade flows. It shows that higher trade flows is associated with higher environmental degradations, both for the importer and the exporter country. But my results also shows a nuance about the level of development. Indeed, when comparing trade between developed countries and Sub-Saharan African countries, natural resources depletion is higher when SSA countries are exporter, compared to the situation where developed countries are exporter. This is due to the high share of commodities into Sub-Saharan African countries exports.

These results have interesting implications to draw some policy recommendations. As we saw that Sub-Saharan African countries are more affected by climate change when bilateral trade flows increase, encouraging the implementation of environmental regulation in those area would provide incentives to adopt greener technologies and more efficient and cleaner production processes. Also strengthening South-South cooperation while encouraging collaboration and knowledge sharing among SSA countries would set path to find innovative solutions to address climate change challenges.

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