INTERNATIONAL MONETARY FUND

Strategies for Africa's Climate Resilience: Trade and Practices

Samantha Borkhoche, Eman Abdulla, Edward Gemayel, Vidhi Maheshwari, and Faten Saliba

WP/25/131

2025
JUL

WORKING PAPER

 WP/25/131

IMF Working Paper
African Department

Strategies for Africa's Climate Resilience: Trade and Practices

Prepared by Samantha Borkhoche, Eman Abdulla, Edward Gemayel, Vidhi Maheshwari, Faten Saliba

Authorized for distribution by Edward Gemayel
July 2025

ABSTRACT: Africa faces growing environmental and developmental pressures that threaten food security, economic stability, and long-term growth. These challenges are compounded by rapid population growth and structural vulnerabilities. This paper explores how shifts toward more sustainable production and practices may help mitigate adverse outcomes in the region. Using local projection methods, we find that increasing the use of goods with lower environmental impact contributes to measurable medium-term improvements. Specifically, we observe reductions in ecological footprint by around 4%, in net emissions embedded in production by 60–100% of total domestic output, and in fine particulate air pollution by roughly 1%. We also introduce a novel Sustainable Practices Index for Sub-Saharan Africa to benchmark country-level performance and foster greater regional alignment. Our findings suggest that countries engaging more actively in such practices experience improvements in environmental outcomes of around 0.3–1.5% in the medium term.

RECOMMENDED CITATION: Borkhoche, S., Abdulla, E., Gemayel, E., Maheshwari, V., & Saliba, F. (2025). "Africa in Transition: Innovation, Adaptation, and Resilience Through Practices." IMF Working Paper No. 25/131 (Washington, DC: International Monetary Fund).

JEL Classification Numbers:	O13, O55, C32, O44
Keywords:	Development strategy; production practices; regional cooperation; externalities; resource use; growth resilience; local projection methods; Sub-Saharan Africa

Author's E-Mail Address:	sab00014@mix.wvu.edu; Eman.Abdulla@warwick.ac.uk; EGemayel@imf.org, vmaheshwari@imf.org ; fsaliba@imf.org

WORKING PAPERS

Strategies for Africa's Climate Resilience: Trade and Practices

Prepared by Samantha Borkhoche (Corresponding Author), Eman Abdulla, Edward Gemayel, Vidhi Maheshwari, and Faten Saliba [1]

[1] We would like to thank the participants at the IMF seminar last August for their valuable feedback, as well as various IMF departments for their helpful comments on an earlier draft of the paper. We would like to extend a special thank you for Zeina Hasna and Samuel Pienknagura for their valuable guidance. The views expressed in this paper are the sole responsibility of the authors and should not be attributed to the International Monetary Fund, its Executive Board, or its management. All errors are our own.

Contents

1 Introduction

Africa is at the forefront of the climate crisis, bearing a disproportionate burden of its impact despite its minimal contribution to global greenhouse gas emissions. The Global Center on Adaptation finds that surface temperatures are increasing across all African regions and the continent is warming faster than the global average over both land and the oceans (Global Center on Adaption, 2022). Per EM-DAT database, between 2011 and 2020, on average approximately 13 million people in Africa were impacted by droughts and 3.5 million were impacted by floods (EM-DAT).

The continent's vulnerability to climate change is stark - manifesting in severe droughts, flooding, and shifting weather patterns - threatening food security and economic stability. Jaramillo et al (2023) further note that underlying fragility like conflict and heavy dependence on rain-fed agriculture exacerbate climate vulnerabilities and vice versa. The concerns are further compounded in the region by a rapidly growing population that demands sustainable economic growth. This juxtaposition of climate vulnerability and development presents a dual challenge that requires a strategic approach for integrating industrialization with climate action. Our paper highlights that Africa has the potential to address these intertwined challenges effectively through sustainable trade.

"sustainable trade" is defined in this paper as trade in environmentally sustainable goods and low-carbon technology. It promotes environmentally sustainable practices and has the potential to decouple economic growth from environmental degradation. Africa's inherent strengths – its renewable energy potential and relatively low emissions – position the region well to lead the world into sustainable trade expansion. By leveraging its substantial natural resources, such as solar energy and vast landscapes suitable for carbon sequestration, Africa can drive industrialization while maintaining a relatively low carbon footprint. The continent's relatively low carbon emissions offer a unique advantage, allowing it to adopt and promote low-carbon technologies and renewable energy sources.

The paper uses local projections analysis to establish the medium-run relationship between sustainable trade and environmental outcomes, such as ecological footprint, net CO2 emissions embedded in trade, and PM2.5 air pollution. The results find that in the medium-term (i.e in 3-5 years), increasing trade in environmental goods and low-carbon technology products can reduce resource use, carbon emissions, and air pollution, leading to improved environmental outcomes by promoting the sustainable use of natural resources and encouraging the adoption of clean technologies.

Trading in environmentally sustainable goods helps mitigate the environmental impact of trade-related economic activities. The use of a time-series analysis is to mitigate the ambiguity of the short-term relationship between sustainable trade and the environment. For instance, the shift to more sustainable technologies might initially increase energy consumption and emissions during the production and installation phases. Furthermore, the benefits of sustainable trade may take time to materialize, leading to a long-run relationship between sustainable trade and environmental outcomes.

Additionally, this paper contextualizes the main results through re-estimation for a sample of Organisation for Economic Co-operation and Development (OECD) countries in order to generate an image for where the SSA region lies in sustainable trade relative to a global sample. Even further, we estimate the effects of sustainable trade on general welfare like air pollution-related deaths and real GDP per capita growth for implications on economic welfare. Lastly, we construct the sustainable Practices Index (SPI) to benchmark individual country performance in the region and facilitate better regional coordination on environmentally sustainable practices.

This index identifies and measures key components of environmentally sustainable policies like renewable energy mix, climate change policies, environmental taxes, and carbon stock. Not only does this index help us standardize environmental practices among the region, but we show evidence that enacting these policies directly decreases environmental outcomes. Our paper is a novel investigation in evaluating the impact of sustainable trade relative to trade on environmental outcomes and analyzes how sustainable practices could be beneficial in the fight against climate change in Sub-Saharan Africa (SSA).

Section 2 delves into existing theoretical and empirical literature on the relationship between trade and environmental quality. Section 3 provides a description of the data and the methodology. Section 4 presents the main findings of the paper and offers potential explanations for short-term and medium-term trends observed in the consequences of trade and sustainable trade on environmental outcomes. Section 5 compares the results to an OECD country sample. Section 6 considers implications of sustainable trade on air pollution-related deaths and real GDP per capita growth. Section 7 explains the construction of the sustainable Practices Index and our related main findings. Section 8 concludes the paper with actionable policy recommendations for Sub-Saharan Africa.

2 Background

2.1 Trade and Economic Growth

There is a general consensus in the literature that trade is a large contributor of economic growth. Frankel and Romer (1999) popularly note that trade is a well-known instrument of economic growth. By allowing countries to specialize in the production of goods and services in which they have a comparative advantage, trade can enhance efficiency, increase output, and stimulate economic growth. Several empirical studies have analyzed the export-led growth expansion hypothesis, with Kavoussi (1984) finding that both low and middle income countries see better economic performance associated with greater export expansion. In the African context, Onafowora and Owoye (1998) find that it is possible to stimulate economic growth in some countries in the region through an outward-looking strategy of export expansion. However, Zahonogo (2016) caveats that the relationship between trade openness and economic growth in not exactly linear in Sub-Saharan Africa. Yet another facet of the debate surrounding trade and economic growth are its environmental consequences. Increased trade and economic growth can lead to higher levels of production and consumption, which often result in greater environmental degradation. The pursuit of economic expansion through trade can drive over-exploitation of natural resources, increase carbon emissions, and pollution. As countries engage more in international trade, the demand for natural resources can escalate, leading to the depletion of these resources alongside significant environmental damage in the form of deforestation, soil erosion, and loss of biodiversity.

Several papers examine the effects of sustainable trade on growth. Ahmed et al (2022) use a variety of indicators like sustainable innovation, clean energy, and sustainable trade, as defined by the OECD, to evaluate their effects on "sustainable" growth which is a variable defined by GDP growth, education, fossil fuel consumption, and CO2 emissions. The analysis is based on South Asian countries, and the paper finds that these indicators positively contribute to sustainable growth. Tariq et al (2023) evaluate a theoretical model for sustainable economic growth with sustainable trade openness (GTO) as one of its components. They find that GTO, along with other sustainable variables, can increase sustainable growth and mitigate carbon emissions. Lastly, Xu (2022) evaluates the impact of natural resources on sustainable growth in China. He finds that sustainable trade plays a moderating role in the relationship. Emphasis should be put on mitigating the effects of climate change while continuing to promote growth in the region.

2.2 Trade and the Environment: Theoretical Background

Research examining the link between trade and environmental outcomes began in the early 1990s with the theoretical seminal paper by Grossman and Krueger (1991) exploring the environmental consequences of the North American Free Trade Agreement. It was followed by Antweiler et al (2001), another theoretical paper that explored the concepts of scale, composition, and technique effects. Scale refers to the size of production, composition refers to the composition of goods by industry, and technique refers to cleaner means of production. The model suggests that free trade can reduce greenhouse gas emissions. Further, Damania et al (2003) finds that corruption reduces environmental policy stringency and is a proper mechanism for how trade liberalization affects the stringency of environmental policy.

Copeland et al (2004) and Cherniwchan et al (2016) more broadly describe the link between trade and environmental outcomes by exploring previous literature and methodologies. Theoretical work by Shapiro (2021) explores tariffs and nontariff barriers on dirty vs. clean industries. It finds that import tariffs are lower on dirty than on clean industries because levels of pollution are not being considered when enacting tariff policy and industries have the ability to move where environmental policy is less stringent. The latter is in reference to the pollution haven hypothesis. Lastly, Duan et al (2021) and Cherniwchan et al (2022) continue this work by suggesting little evidence for the pollution haven hypothesis.

2.3 Trade and the Environment: Empirical Background

On empirical work analyzing the general link between trade and environmental outcomes, Kim et al (2019) finds that trade between developed and developing countries have heterogeneous pollution effects, but trade among developing nations tends to reduce CO2 emissions. They find evidence for the Environmental Kuznets hypothesis (EKC) which describes that environmental pressure increases with GDP but, after a certain income level, it declines with growth. Lin et al (2016) disagree by stating that, specific to Africa, the EKC, or GDP growth alone, does not provide enough benefit for environmental policy and there should be a focus on encouraging energy efficiency and enhancing the use of clean energy. This paper, among others, explores the negative relationship between population growth and urbanisation on CO2 emissions.

Further empirical work specific to SSA countries shows relatively mixed results between trade and environmental outcomes. A study by Ibrahim et al (2022) suggests a negative relationship between trade facilitation and environmental pollution, indicating that free trade can be beneficial on lowering pollution. However, Bekoe and Jalloh (2023) conclude the opposite, that free trade is detrimental to environment quality in the long-run. On policy, Shu et al (2024) finds that tariffs could contribute to strengthening environmental quality.

Contradictory, Dada et al (2024) state that tariffs have a significant positive effect on carbon footprints in countries with relatively lower pollution. However, the effect turns negative in countries with higher levels of pollution. Udeagha et al (2022) suggests implementing more environmental policies focusing on tariffs on goods with high ecological footprint or subsidies on environmentally-friendly goods. Ibrahim et al (2016) emphasize the importance of institutional quality and states that it must be at a certain competent level before trade can reap the reward of positive effects on environmental outcomes. Results from Olaoye et al (2024) show that energy use negatively affects environmental quality and there should be stricter regulations surrounding energy policy.

2.4 Contribution to the Literature

Our paper makes several contributions to the literature on environmental economics and sustainable trade. First, it confirms the Environmental Kuznets Curve (EKC) hypothesis and demonstrates that the trade of sustainable products reduces the ecological footprint in host countries. Unlike Ben Zineb (2019), who analyzes the impact of trade in environmentally preferable products and clean technologies on air quality up to 2012, our study provides a more current analysis focusing on Sub-Saharan Africa (SSA). This focus is significant because SSA holds unique potential to champion climate-resilient trade, given its vulnerabilities to climate change and relatively low emissions compared to other regions. Additionally, our analysis employs a broader definition of trade in environmental goods and evaluates its effects across multiple environmental dimensions, including ecological footprints, carbon emissions embedded in trade, and air quality—filling a notable gap in the literature.

Second, while Ali et al (2023) examines the impact of environmental goods and low-carbon technology products on environmental degradation distribution in G20 countries using the method of moments quantile regression, our study applies the local projections method. This approach enables a dynamic examination of the effects of "sustainable trade" and related practices on environmental outcomes, providing actionable policy recommendations.

Finally, our paper introduces the Sustainable Practices Index (SPI) to evaluate how environmental policy influences environmental outcomes. This analysis aligns more closely with Can et al (2022), which developed a sustainable Trade Index (GTI) by measuring the net exports of sustainable goods as a percentage of GDP for 31 OECD countries. However, while the GTI by Can et al (2022) is referred to as an "index," it simply represents the percentage of sustainable goods relative to total goods. In contrast, our index incorporates a range of environmental practice variables with tangible implications for policy and environmental outcomes.

3 Data and Methodology

3.1 Environmental Outcomes

For the environmental outcomes data, this paper uses three indicators - i) Ecological Footprint, ii) Net CO2 emissions embedded in trade, iii) PM2.5 air pollution

Ecological footprint is defined by the Global Footprint Network[1] as the ecological resource use and resource capacity of nations over time. Its components include grazing land, cropland, carbon, fishing grounds, etc. As there are a finite amount of resources, increasing one's ecological footprint could contribute

[1] https://data.footprintnetwork.org//

to the over-exploitation of natural resources which has negative impacts on the environment. We use the log differences to capture percentage change in ecological footprint over time. A positive value captures environmental degradation as it is an increase in resource use.

To include an environmental variable more directly affected by trade, this paper uses net CO2 emissions embedded in trade (per the Global Carbon Budget, sourced from Our World in Data[2]). This data is defined as the value of CO2 emissions in imports subtracted by the value of CO2 emissions in exports as a percent of total domestic production. Thus, if these countries have a positive value, it means they are a net importer of CO2 emissions. CO2 emissions above a natural level traps heat in the atmosphere and raises global temperatures and, as a result, contributes to climate change. To be a net importer means that the country is importing goods with high emissions relative to their exports. This variables helps us directly connect the effects of sustainable trade to CO2 emissions from trade.

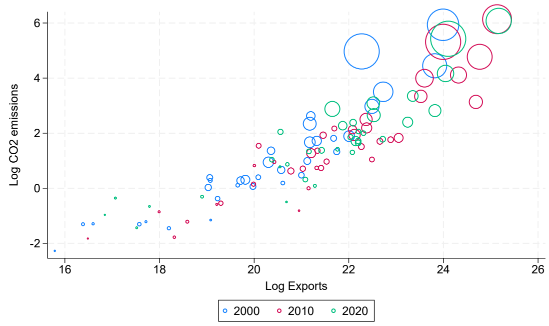
Since this paper seeks to understand the effect of sustainable trade on local emissions, an additional dependent variable we measure is the percentage change of PM2.5. PM2.5 is defined as tiny particles in the air that are 2.5 micrometers or less in diameter. Much of PM2.5 pollution is from the combustion of gasoline, oil, diesel fuel or wood. PM2.5 contributes to air pollution and is harmful on the lungs. This data is taken from the Global Burden of Disease (GBD) Study in 2021 from the Institute for Health Metrics and Evaluation (IHME)[3]. We use log differences to capture the percentage change in air pollution. An increase in this value means that there is more PM2.5 particles in the air which contributes to air pollution.

As there are mixed findings in the literature on the effects of trade on environmental outcomes, Figure 1 plots the relationship between exports, imports and CO2 emissions for a sample of African countries compared to a global sample for the years 2000, 2010, and 2020. It indicates a positive association between trade and CO2 emissions for both Africa and the global sample. However, the association between the two variables in African countries is much lower, indicating that this relationship is not as strong in this region. The size of the circles represent the size of the economy based on their GDP. The relationship appears to be stronger for countries with larger economies.

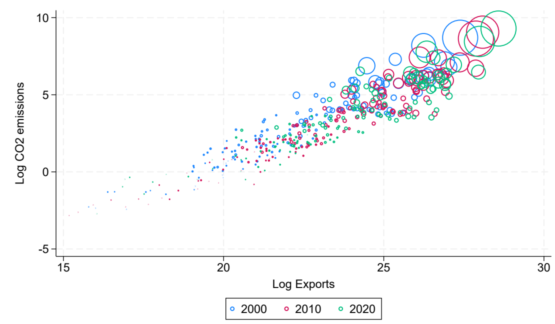
Figure 2 plots the same relationship using ecological footprint as the environmental outcome. There is a positive relationship between trade and ecological footprint, but the global sample is stronger than the Africa samples, albeit not by too much. Again, the relationship is stronger for countries with larger economies. These plots emphasize the importance of looking specifically at the Sub-Saharan Africa region as sustainable trade will have different effects on environmental outcomes relative to the rest of the globe.

Figure 3a shows the median value of the log difference in ecological footprint among the country sample

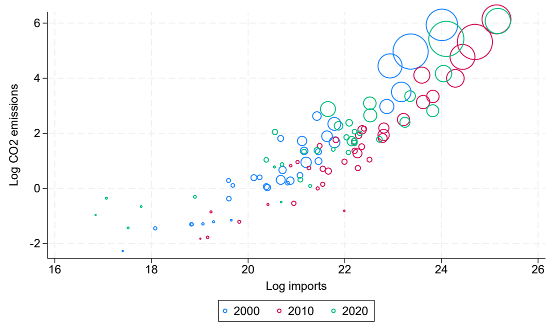
[2] https://ourworldindata.org/grapher/co-emissions-embedded-in-global-trade
[3] https://vizhub.healthdata.org/gbd-compare/



(a) Africa Sample: Exports



(b) Global Sample: Exports



(c) Africa Sample: Imports

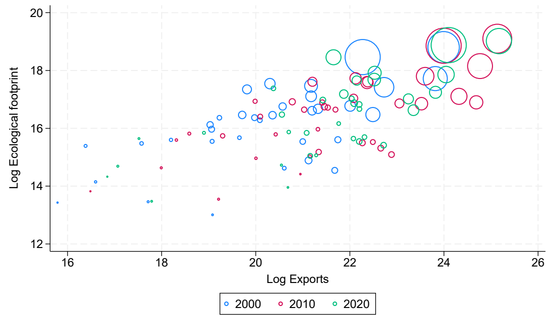
(d) Global Sample: Imports

Note: The size of the circle is indicative of the size of the economy based on GDP.

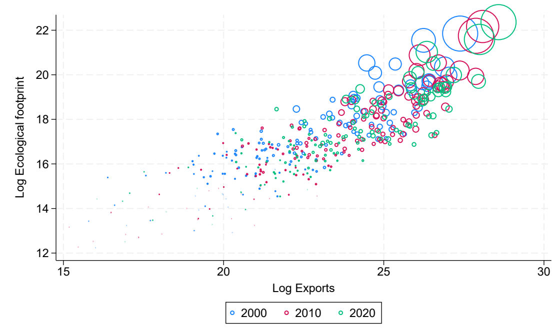
Figure 1: Relationship Between Trade and CO2 Emissions

each year. This figure shows that there is almost always a positive number, indicating that there are constant increases in ecological footprint over the sample period. Likewise, Figure 3b shows the median value of net CO2 emissions embedded in trade among the country sample each year. For every year, the median is a positive number, indicating that most SSA countries are net importers of CO2 emissions. Figure 3c shows the median percentage change of PM2.5 in units of micrograms per cubic meter. The values stay consistent until after 2010 where they become much more volatile, hovering over and under 0. This indicates that some years had heightened levels of air pollution and other years they decreased.

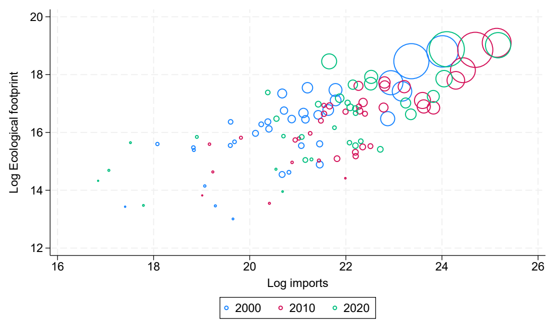
There is clear heterogeneity among the sample of SSA countries. For the GCB net emissions, we see that the inter-quartile range is quite large and there may be a handful of examples where the countries have a negative value, meaning that they were net exporters of CO2 emissions. This range is tighter for ecological footprint, indicating that there is less heterogeneity among the sample in resource use. Lastly, for our measure of air pollution, all years except for 2013 and 2015 indicate very little heterogeneity in our sample. Comparing these three variables in the analysis will give us a consistent and detailed assessment at how sustainable trade affects the environment.



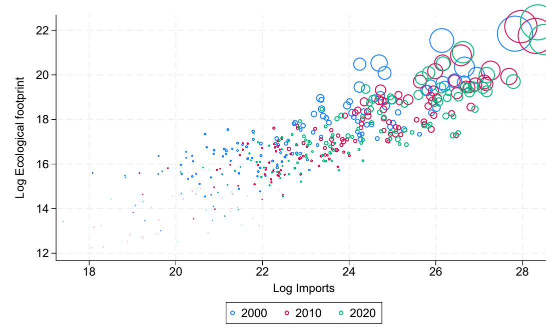
(a) Africa Sample: Exports



(b) Global Sample: Exports



(c) Africa Sample: Imports



(d) Global Sample: Imports

Note: The size of the circle is indicative of the size of the economy based on GDP.

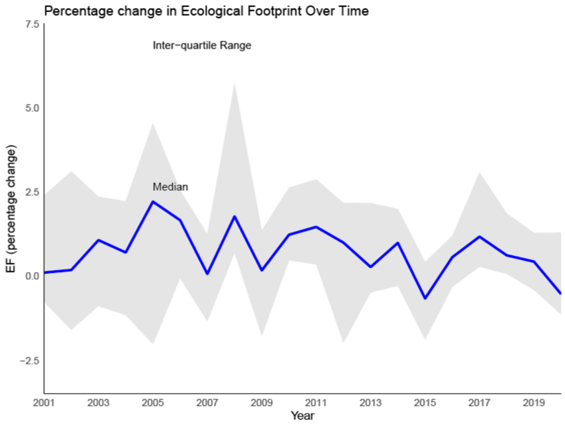
Figure 2: Relationship Between Trade and Ecological Footprint

3.2 Trade and sustainable Trade

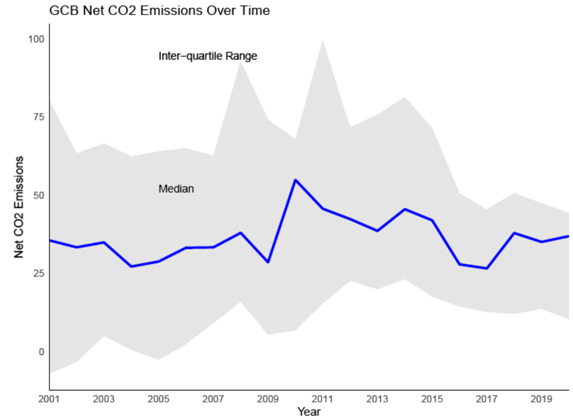
Our paper used two definitions of 'sustainable trade'. The first is a broader examination including 224 environmental goods per UN Comtrade[4]. These goods are defined as having a connection to environmental protection like pollution and resource management and goods that have been modified to be more "environmentally friendly". The second definition of 'sustainable trade' is narrower and more policy-actionable since it focuses on trade in low carbon technology products. The IMF Climate Change Dashboard identifies 125 traded low carbon goods defined as products that produce less pollution than their traditional energy counterparts. This includes low carbon equipment like wind turbines, solar panels, biomass systems, and carbon capture equipment[5].

Figure 4 shows the median value of trade in environmental goods (per the broader UN Comtrade definition) as a % of GDP. These values are very low relative to general trade, and they stay consistent after 2008, indicating little increase in the trade of sustainable goods in recent years. Figure 5 shows the median value of trade in low carbon technology products as a % of GDP. This is comparable to Figure 4

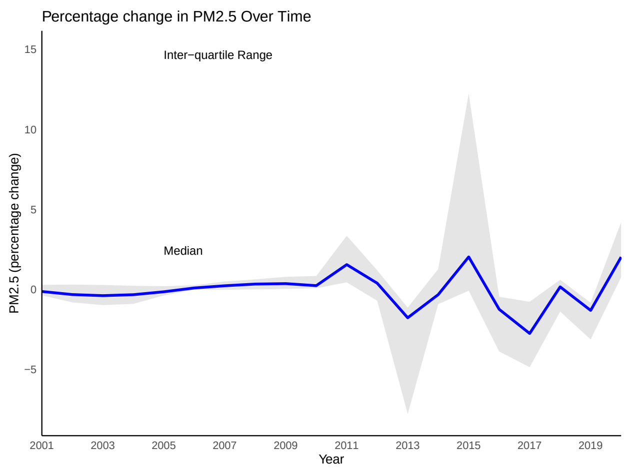
[4]https://climatedata.imf.org/datasets/8636ce866c8a404b8d9baeaffa2c6cb3$_0$/*about*
[5]https://climatedata.imf.org/datasets/1d33174e9e46429d9e570d539556f66a$_0$/*about*



(a) GFN Median Percentage Change in Ecological Footprint



(b) GCB Median Net CO2 Emissions in Trade



(c) PM2.5 Median Percentage Change

Figure 3: Key variables over time

and also exhibits the slowdown of trade in low carbon technology products after 2008. The mean value of the UN Comtrade definition of sustainable trade is higher than trade in low-carbon technology. This could be due to having a higher amount of environmental goods defined as “sustainable”.

To contextualize our results on the effect of sustainable trade on environmental outcomes, we also analyse the impact of general trade activity on environmental outcomes. The World Bank Development Indicators define trade as the total value of imports and exports in US Dollars as a % of GDP. Table 1 shows the mix of variables included in each regression numbered 1-4. Each analysis is repeated by replacing general trade as the shock variable, resulting in a total of 8 regressions.

To put our country sample into global perspective, Figures 6 and 7 show the median values of environmental goods for both the UN Comtrade and TLCT definitions for Organisation for Economic

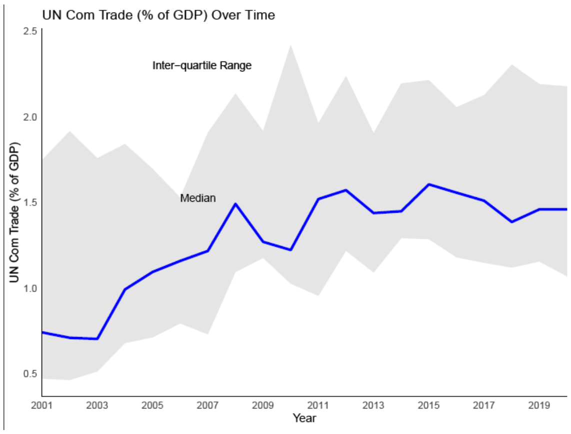


Figure 4: UN Comtrade Median Value of sustainable Goods (% of GDP)

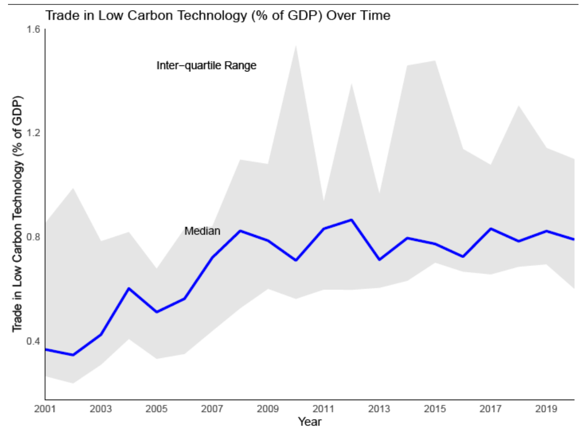


Figure 5: TLCT Median Value of Low Carbon Goods (% of GDP)

Table 1: Variables Included in each Regression

Analysis	Dependent Variable	Sustainable Trade Independent Variable
1	Global Footprint Network Ecological Footprint	UN Comtrade Green Trade
2	Global Footprint Network Ecological Footprint	Trade in Low Carbon Technology
3	Global Carbon Footprint Net CO2 Emissions	UN Comtrade Green Trade
4	Global Carbon Footprint Net CO2 Emissions	Trade in Low Carbon Technology
5	Global Burden of Disease PM2.5	UN Comtrade Green Trade
6	Global Burden of Disease PM2.5	Trade in Low Carbon Technology
Note:	Each analysis is repeated with World Bank general trade (% of GDP) as the main independent variable for comparison. The sustainable trade independent variables are sourced from the IMF Climate Change Dashboard	

Co-operation and Development (OECD) countries.[6] As the OECD country sample includes more developed countries who are better equip to make more economically sustainable decisions, they have much higher values of traded environmental goods than our SSA country sample. On a global scale, countries in SSA trade environmental goods at much lower rates.

3.3 Main Control Variables

Based on previous literature[7], we include three control variables in our analysis. One is gross domestic product (GDP) per capita (% annual growth) measured in constant LCU as defined by the World Bank. We control for GDP under the assumption that, as evidenced from the Environmental Kuznets Curve, income and pollution are statistically related. Another is population growth (POP) (% annual growth). As a

[6]The 37 countries are: Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States of America

[7]See references section

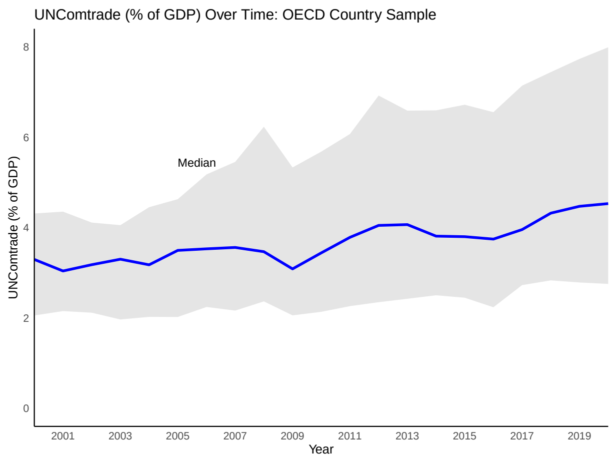


Figure 6: UN Comtrade Median Value of sustainable Goods (% of GDP): OECD Country Sample

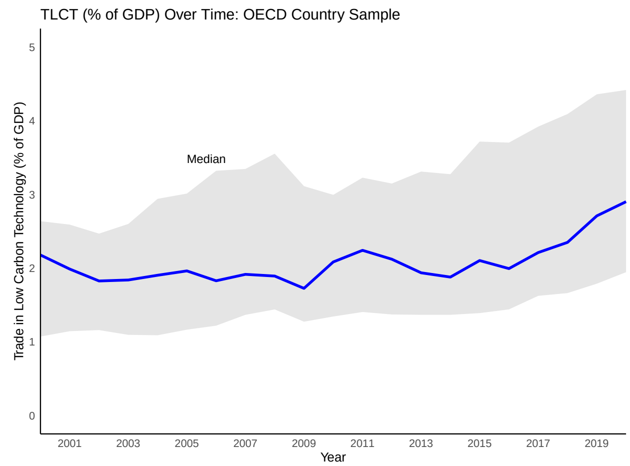


Figure 7: TLCT Median Value of Low Carbon Goods (% of GDP): OECD Country Sample

population grows, naturally, the country will have a larger environmental footprint and contribute more to environmental degradation. A third is urbanization growth (URB) (% annual growth). The assumption here is that as a country moves to be more industrial or there are larger collections of cities, production and emissions will increase. We source these variables from the World Bank Development Indicators.

3.4 Summary Statistics

To compare between trade and sustainable trade, we limited our sample to the years 2001-2020 at a yearly frequency. Our main results include the full sample of countries based on data availability. We collect data on the following 17 countries: Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cote d'Ivoire, Eswatini, Madagascar, Mauritius, Namibia, Niger, Rwanda, Senegal, South Africa, Tanzania, Uganda, and Zimbabwe. Figure 8 shows the breakdown of our country sample by income level.

To ensure the effects of increasing trade in sustainable are captured, we control for trade as a % of GDP in our sustainable trade analyses. In the same vein, we control for sustainable trade in our general trade analyses to make sure we are only looking at the effects of trade. We do this by calculating the ratio of the total value of imports and exports of sustainable goods divided by the value of total trade in US dollars. The value for total trade is sourced from the IMF database. We do this for each definition of sustainable trade and their respective country samples.

Table 2 shows the descriptive statistics for each analysis. The number of observations tells us there is between 13 and 16 countries in each analysis. Both definitions of sustainable trade as a % of GDP is at a much lower mean level than general trade as a % of GDP, indicating that SSA is not trading a lot of "sustainable" goods. The mean values of our GFN and GCB environmental outcomes are positive, indicating

Low Income	Lower Middle Income	Upper Middle Income
Burkina Faso, **Burundi,** Madagascar, **Niger,** Rwanda, Uganda	Benin, *Cameroon,* Cote d'Ivoire, **Eswatini,** Senegal, Tanzania, Zimbabwe	Botswana, Mauritius, Namibia, South Africa

Note: The *italicized* country is not in the UN Comtrade regressions and the **bolded** countries are not in the GCB regressions. The underlined country is not in the TLCT regressions.

Figure 8: Countries in Data Sample by Income

that resource use is increasing and CO2 emissions in trade are heavily focused on imports. The mean value of our GBD environmental outcome is negative and close to zero, indicating that, on average, there is little change in air pollution among our sample.

Table 2: Analysis Summary Statistics

Analysis	Statistic	N	Mean	St. Dev.	Min	Med	Max
1 & 5							
	UN Comtrade	320	1.59	0.92	0.26	1.38	5.75
	WB Trade	320	62.30	27.92	20.96	55.05	175.80
	GFN EF	320	0.75	3.72	−14.08	0.73	22.84
	GBD PM2.5	320	−0.07	3.38	−15.16	0.01	20.18
	Trade Ratio	320	0.20	0.19	0.02	0.14	1.26
3							
	UN Comtrade	260	1.58	0.92	0.26	1.40	5.75
	WB Trade	260	62.63	24.67	27.49	56.60	129.78
	GCB Net CO2	260	37.68	46.30	−43.84	31.00	258.22
2 & 6							
	TLCT	320	0.83	0.51	0.12	0.71	3.69
	WB Trade	320	63.09	27.20	27.49	55.29	175.80
	GFN EF	320	0.77	3.62	−14.08	0.73	22.84
	GBD PM2.5	320	−0.08	3.52	−15.16	−0.08	20.18
	Trade Ratio	320	0.11	0.10	0.01	0.09	0.86
4							
	TLCT	280	0.84	0.52	0.12	0.72	3.69
	WB Trade	280	61.43	24.20	27.49	55.39	129.78
	GCB Net CO2	280	36.09	45.04	−43.84	28.94	258.22
Controls							
	GDP % growth		1.55	4.22	−18.32	2.01	19.94
	POP % growth		3.52	1.78	−0.15	3.67	7.60
	URB % growth		3.54	1.65	−0.15	3.68	7.60

3.5 Local Projections Analysis

The paper uses linear local projection analysis as described by Jorda (2005) and as further described by Jorda and Taylor (2024). This paper adopts a time series analysis to better analyze the medium term effects of sustainable trade on account of inertia in adoption of environmental goods and low carbon technology products. For instance, after importing wind turbines and solar panels, the necessary infrastructure and workforce must be established to assemble, operate, and transition to renewable energy. Local projections is a favorable time-series method because we cannot assume that the many variables in our series are stationary.

The model estimates impulse response functions from a 1-standard deviation increase in the independent, or shock, variable. In this case, the shock variable would be either trade in environmental goods or trade in low carbon technology products, depending on the analysis. The impulse response functions are estimated at each period of interest rather than extrapolating into far horizons as defined by local projections methodology. The analysis uses the shock variable lagged by one year as an instrumental variable to eliminate any endogeneity issues. The equation below describes the regression technique:

$$logp_{i,t+h} - logp_{i,t-1} = \alpha_i^h + \sum_{n=1}^{2} \beta_{t-n} p_{i,t-n} + \gamma^h \phi_{i,t} + \lambda_{i,n}^h X_{i,n}^h + \eta_i + \nu_t + \epsilon_{i,t+h}^h \tag{1}$$

where p indicates the ecological footprint variable or the PM2.5 variable and ϕ indicates the sustainable trade or trade variable for each country i at time t. X indicates a matrix of control variables including GDP, population, and urbanization. In addition, the sustainable trade regressions control for general trade as a percentage of GDP, and the general trade regressions control for sustainable trade as a percentage of general trade. η and ν indicate country and time fixed effects, respectively. Two lags are estimated as established by the AIC criteria. Local projections show a one-standard deviation shock on the ϕ variable over 5 horizons, h = 0, 1, 2, ... , 5. The results estimate the cumulative impulse responses over time. The confidence intervals are measured at the 67% level, consistent with previous studies such as Stock and Watson (2005).[8] The model uses Newey-West standard errors. The equation below is similar except the GCB Net CO2 emissions variable is the dependent variable.

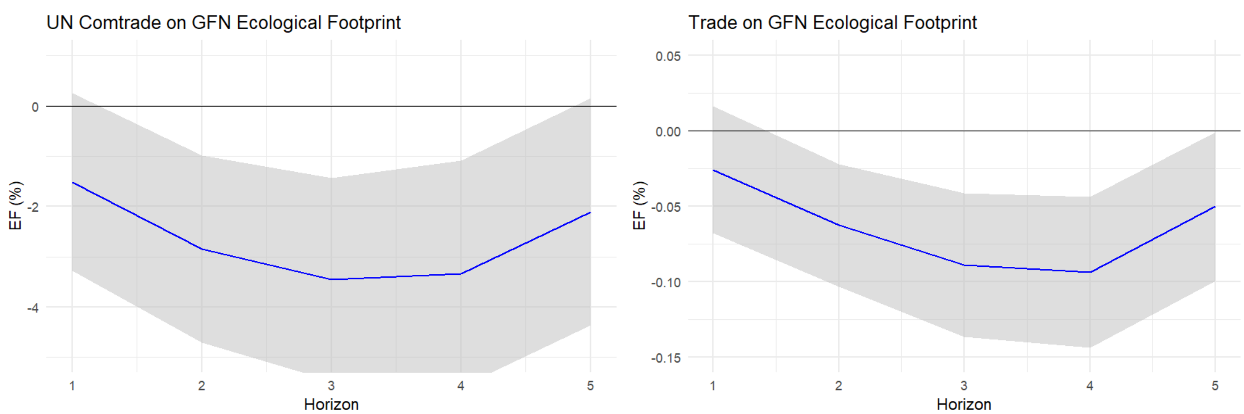
$$p_{i,t+h} = \alpha_i^h + \sum_{n=1}^{2} \beta_{t-n} p_{i,t-n} + \gamma^h \phi_{i,t} + \lambda_{i,n}^h X_{i,n}^h + \eta_i + \nu_t + \epsilon_{i,t+h}^h \tag{2}$$

All specifications are the same as equation 1.

[8]The estimation was repeated at 90% leve confidence interval. Most of the main results still hold, but the peak decrease at horizon 3.

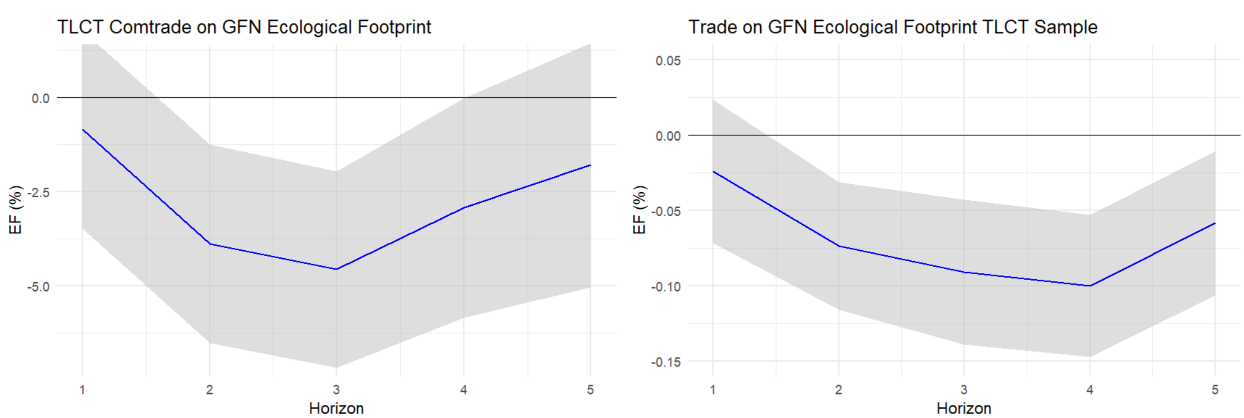
4 Effect of sustainable Trade on Environment Outcomes

Figures 9-14 show the cumulative impulse response functions of a positive one-standard deviation shock in the sustainable trade and trade variables on the environmental outcome variables. Figure 9 shows the results for shocking sustainable trade in environmental goods on ecological footprint compared to the results from shocking general trade on ecological footprint. Figure 10 shows the results from shocking trade in low carbon technology products on ecological footprint. Trade in environmental goods leads to a significant improvement in the ecological footprint, starting from the second year, with the most substantial gains (around 3.5%) observed in the third and fourth years. Similarly, trade in low-carbon technology products follows a comparable pattern, achieving the greatest gains (just under 5%) in the third year.



(a) sustainable Trade & Ecological Footprint (b) Trade & Ecological Footprint

Figure 9: UN Comtrade sustainable Trade & Trade with GFN Ecological Footprint (Analysis 1)

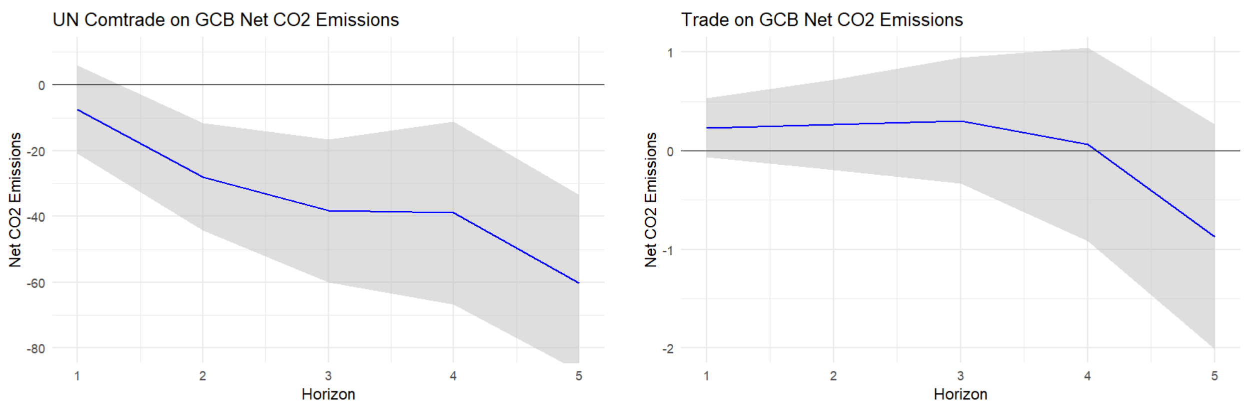


(a) Low Carbon Trade & Ecological Footprint (b) Trade & Ecological Footprint

Figure 10: TLCT & Trade with GFN Ecological Footprint (Analysis 2)

Notably, when compared to the impact of general trade, trade in environmental goods and low-carbon technology products has a more pronounced effect on reducing the ecological footprint, and the improvements occur more rapidly with 'sustainable trade' than with trade in all goods. The consistency between the results with both definitions of sustainable trade indicate that there is a strong medium-term negative relationship between sustainable trade and ecological footprint.

Figure 11 and 12 show that general trade does not significantly influence the reduction of carbon emissions embedded in trade, either in the short term or over the medium term. However, trade in environmental goods and low-carbon technology products shows a markedly different impact. Specifically, trade in environmental goods leads to a cumulative reduction in embedded carbon emissions of approximately 60% over five years, while trade in low-carbon technology products is even more effective, achieving a cumulative reduction of around 100% over the same period.[9] These results suggest that targeted trade in environmentally friendly and low-carbon technologies can play a critical role in reducing the carbon intensity of trade, particularly in the medium term, whereas general trade lacks the focused impact necessary to drive significant emissions reductions.



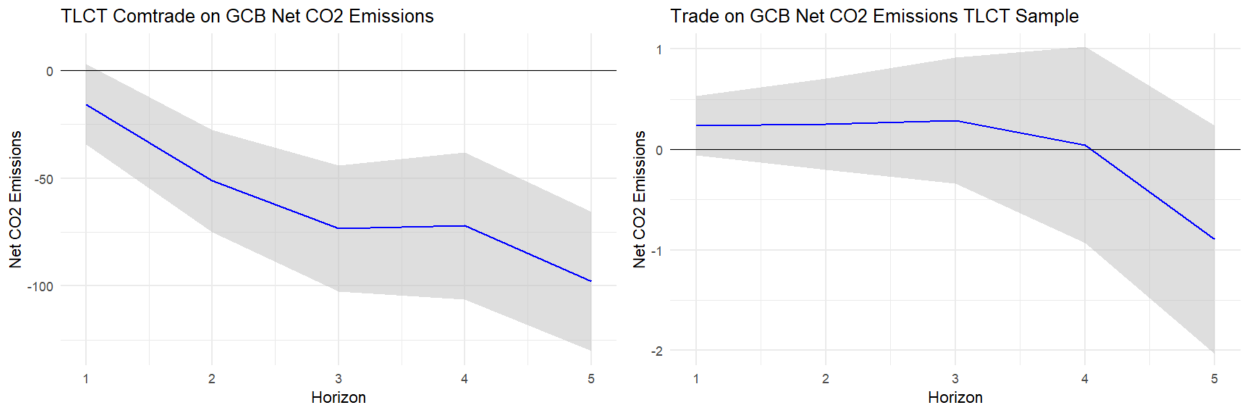
(a) sustainable Trade & Net CO2 Emissions in Trade

(b) Trade & Net CO2 Emissions in Trade

Figure 11: UN Comtrade sustainable Trade & Trade with GCB Net CO2 Emissions (Analysis 3)

When analyzing our third environmental output, particulate matter 2.5 (PM2.5), Figure 13 compares the impact of the sustainable trade variable on PM2.5 with that of general trade. Consistent with previous findings, sustainable trade leads to a reduction in air pollution by approximately 1% after 3-4 years. This impact is notably larger than that of general trade, which shows minimal and statistically insignificant reductions in air pollution. However, by the fifth year, the impulse response functions (IRFs) become insignificant, suggesting that while sustainable trade has a notable medium-term effect on reducing air pollution, its influence diminishes over the long term. Figure 14, which analyzes the same regression using

[9] Botswana and Namibia had high levels of CO2 and were outliers. After removing them from the sample, the estimates decreased to between [−25%, −35%]. The IRF results are in Figure A1 in the appendix.

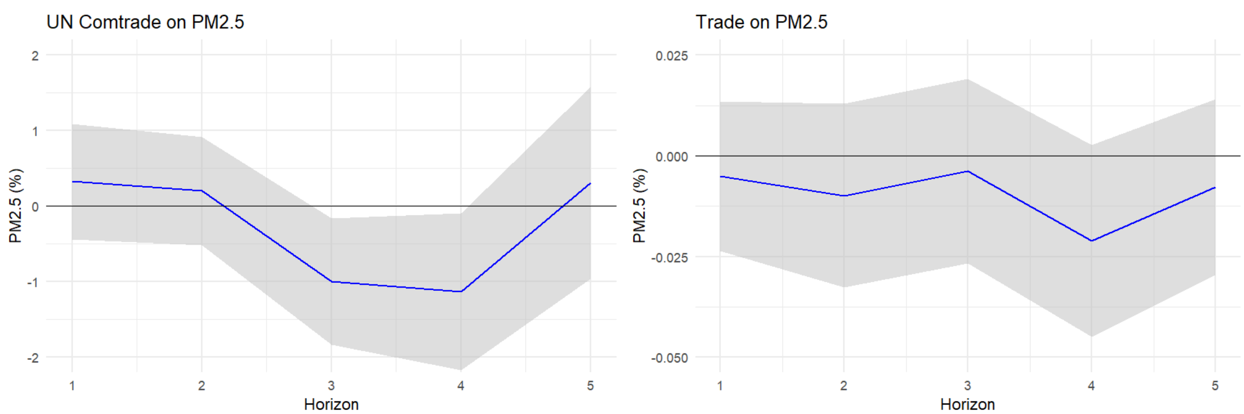


(a) Low Carbon Trade & Net CO2 Emissions in Trade

(b) Trade & Net CO2 Emissions in Trade

Figure 12: TLCT & Trade with GCB Net CO2 Emissions (Analysis 4)

the TLCT sustainable trade variable, reflects similar peak reductions followed by a gradual return to zero, indicating that the initial benefits of sustainable trade do not sustain beyond the medium term.

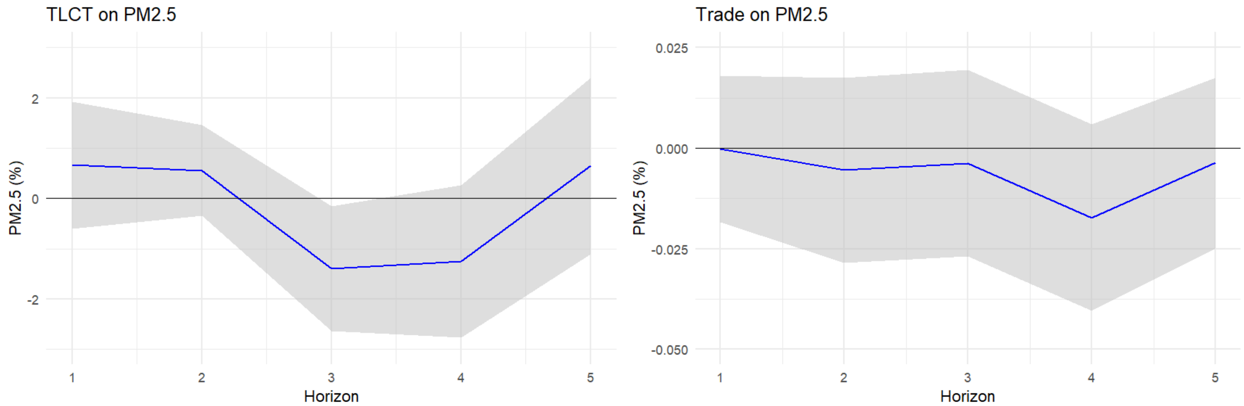


(a) sustainable Trade & PM2.5

(b) Trade & PM2.5

Figure 13: UN Comtrade sustainable Trade & Trade with GBD PM2.5 (Analysis 5)

In summary, the analysis reveals a significant medium-term relationship between sustainable trade and improved environmental outcomes. An increase in sustainable trade (trade in environmental goods or trade in low carbon technology) results in a reduction of negative environmental impacts, with the greatest benefits emerging after 3 to 5 years. This time lag is likely due to the period required for building the necessary infrastructure and integrating the traded sustainable goods into practical use. For these benefits to materialize, countries need to ensure they have adequate labor, human capital, and resources to effectively utilize the imported sustainable technologies, which can extend the implementation timeline. Notably, the positive impact of sustainable trade on the environment is considerably greater and faster



(a) Low Carbon Trade & PM2.5

(b) Trade & PM2.5

Figure 14: TLCT & Trade with GBD PM2.5 (Analysis 6)

than that of general trade.

5 OECD Country Sample Comparison

Since this paper is unique in its analysis of the impact of sustainable trade on environmental outcomes in SSA using latest data, it is important to put the main results described above into context. Because there is very little literature using these variables or running similar regressions, the main analyses were re-evaluated using countries part of the Organisation for Economic Co-operation and Development (OECD). Most of these countries have developed economies, democracies, and open and free market economies. This makes it a good comparison group because of their openness in trade. Table 3 shows the summary statistics for all of the variables in each regression for the OECD country sample.[10] Compared to our SSA sample, these countries have higher levels of sustainable trade and general trade. They have lower levels of resource use, net CO2 emissions in trade, and PM2.5 level of air pollution. Also, they have lower rates of GDP, population, and urbanization growth. Hallmark differences between developing and developed are captured when comparing the variables between both country samples. The regressions are run using specifications from equation 1 and 2. Figures 15-17 show the cumulative impulse response functions from a 1-standard deviation increase in the sustainable trade or general trade variable on all three dependent variables. The top left shows the effect from UN Comtrade sustainable trade, top right shows the effect from trade in low carbon technology, and the bottom graph shows the effect from general trade. Figure 15 shows the regressions on GFN Ecological Footprint. As before, the impact of sustainable trade show lag effects, with peak decreases at three years. However, the decreases are smaller than the main results. With general trade, there is a consistent increase,

[10] Analysis 1 does not include Iceland and analysis 2 does not include Iceland or Norway due to data limitations.

Table 3: Analysis Summary Statistics: OECD Country Sample

Analysis	Statistic	N	Mean	St. Dev.	Min	Med	Max
1							
	UN Comtrade	720	4.68	3.37	0.99	3.78	20.51
	TLCT	720	2.65	1.90	0.45	2.08	13.84
	WB Trade	720	94.38	55.93	19.56	78.04	382.35
	GFN EF	720	−0.23	3.22	−19.63	−0.18	15.40
	UN Trade Ratio	720	14.90	42.41	0.27	6.11	326.31
2							
	UN Comtrade	720	4.75	3.40	0.99	3.82	20.51
	TLCT	720	2.68	1.92	0.45	2.11	13.84
	WB Trade	720	95.09	56.56	19.56	79.74	382.35
	GCB Net CO2	720	28.00	38.89	−28.11	18.71	312.37
3							
	UN Comtrade	740	4.61	3.36	0.99	3.68	20.51
	TLCT	740	2.65	1.90	0.45	2.08	13.84
	WB Trade	740	94.10	55.23	19.56	78.27	382.25
	GBD PM2.5	740	−0.94	2.15	−11.63	0.75	10.27
	UN Trade Ratio	740	14.59	41.87	0.27	6.06	326.31
Controls							
	GDP % growth	740	1.54	3.47	−14.46	1.64	23.30
	POP % growth	740	0.57	0.76	−2.26	0.53	2.89
	URB % growth	740	0.86	0.92	−2.28	0.85	4.12

meaning that increasing trade actually increases the use of resources over time. This is the opposite effect from our SSA sample.

Figure 16 shows the effect on GCB net CO2 emission embedded in trade. The effect of sustainable trade is near zero and insignificant, indicating that there is no effect between sustainable trade and net CO2 emissions. However, increasing trade increases net CO2 emissions by 0.3% after five years. Figure 17 shows the effect on PM2.5 level of air pollution. There is very small and mostly insignificant effects on sustainable trade and trade on air pollution in the OECD sample. To summarize these results in relation to our main results using the Sub-Saharan Africa country sample, the effect of increasing sustainable trade on environmental outcomes is much smaller, and increasing trade actually has positive effects on environmental outcomes, indicating that trade is detrimental to the environment for OECD countries.

The difference may be because of the classic ”catch-up effect”, in which OECD countries have already made significant progresses in sustainable trade and climate change policy compared to SSA, so any increases may be less effective than the SSA region where there is a lot more room for growth in the sustainable sector. This comparison shows that the effects of sustainable trade are much more significant and important in SSA than they are in other parts of the world.

Figure 15: sustainable Trade & Trade on GFN Ecological Footprint: OECD Country Sample

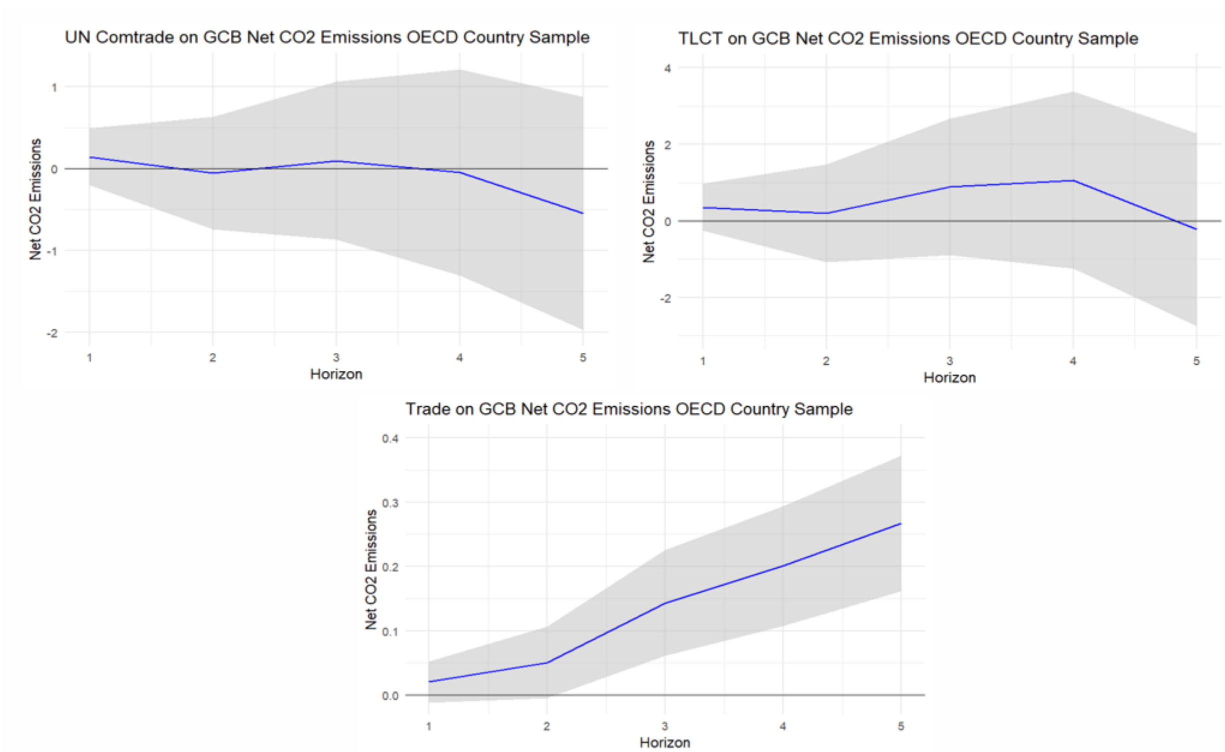


Figure 16: sustainable Trade & Trade on GCB Net CO2 Emissions: OECD Country Sample

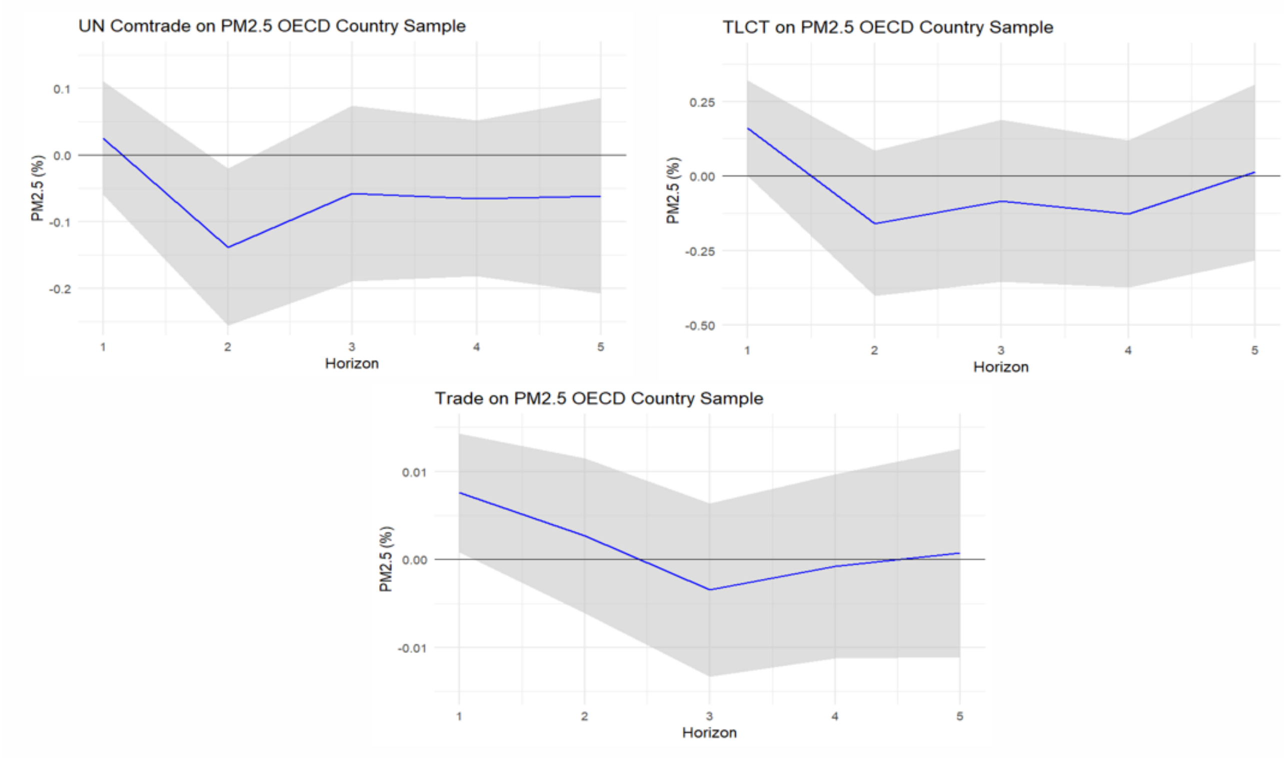


Figure 17: sustainable Trade & Trade on GBD PM2.5: OECD Country Sample

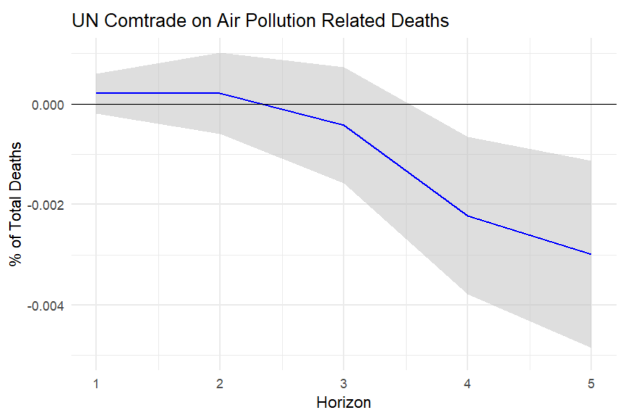
6 Implications on Economic Welfare

The main results show that the effects of sustainable trade are beneficial for the environment. As there are risks that come from pollution and the effects of climate change, these results should translate positively to welfare outcomes related to pollution. The Global Burden of Disease study has data on the % of total deaths related to air pollution, or PM2.5 particles in other words. This is defined as all causes of death related to particulate matter. To find out if sustainable trade has any effect on general welfare, this paper evaluates the effect of sustainable trade on air pollution-related deaths using the specifications of equation 2. Table 4describes the summary statistics for PM2.5 related deaths. The levels are very low.

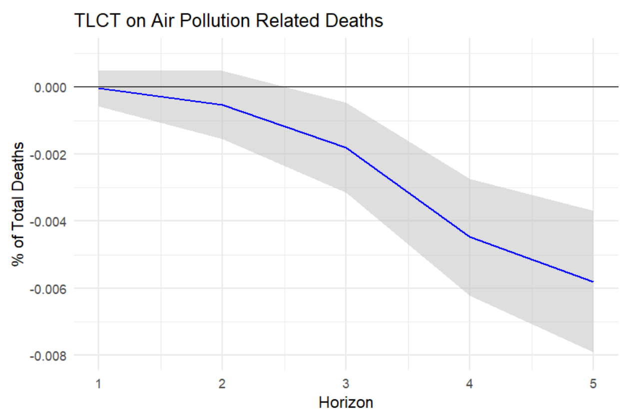
Table 4: PM2.5 Related Deaths Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Med	Max
GBD PM2.5	320	0.02	0.01	0.01	0.02	0.05

Figure 18 shows the results from a 1 standard-deviation increase in sustainable trade on air pollution-related deaths. The left graph shows the UN Comtrade sustainable trade effect and the right graph shows the TLCT effect. There is no immediate or significant relationship, but after 3-5 years, the percent of deaths associated with air pollution decreases, peaking at 0.003-0.006% after five years. These levels are understandably small as there are generally low amounts of air pollution-related deaths. However, reducing the negative effects of the environment through sustainable trade can ultimately save lives.



(a) UN Comtrade sustainable Trade & PM2.5 Related Deaths



(b) TLCT & PM2.5 Related Deaths

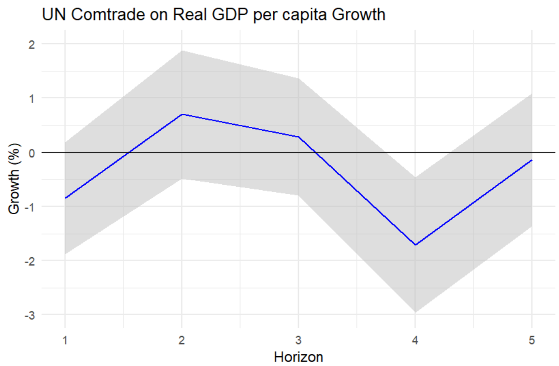
Figure 18: sustainable Trade on GBD PM2.5 Related Deaths

Relating the discussion to previous literature, there may be worry that increasing sustainable trade could affect economic growth because there is believed to be a trade-off between growth and environmental sustainability. Using the same specification as equation 2, the regressions are re-estimated with real GDP per capita growth as the dependent variable. All control variables except for GDP remain the same. However, these IRFs are non-cumulative. Figure 19 shows the impulse response functions with UN Comtrade sustainable trade as the independent variable on the top left, TLCT as the independent variable on the top right, general trade for our SSA country sample as the independent variable on the bottom left, and general trade for our OECD country sample on the bottom right. This means that these variables in the context of SSA have little relationship. As expected, general trade has a positive and significant effect on GDP for both the SSA and OECD country samples.

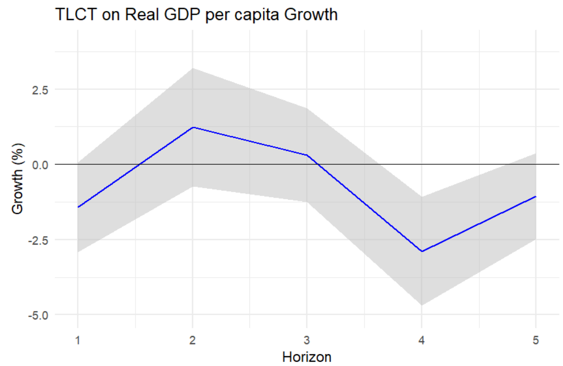
In order to accurately compare the costs and benefits from sustainable trade relative to general trade, it is imperative to understand the meaning behind these impulse response functions in dollar terms for each regression. For the UN Comtrade SSA sample, a one-standard deviation increase in sustainable trade as a % of GDP corresponds to a $309.67 million increase.[11] Using the mean GDP per capita (constant international dollars) of $5,874.31 for the sample, it is calculated that increasing sustainable trade by one standard deviation decreases real GDP per capita by $100.44 over the five year horizon.[12]

For the TLCT variable, a one-standard deviation increase in sustainable trade as a % of GDP corresponds to a $183.456 million increase. The mean GDP per capita for this country sample is $6,086.80. Using the

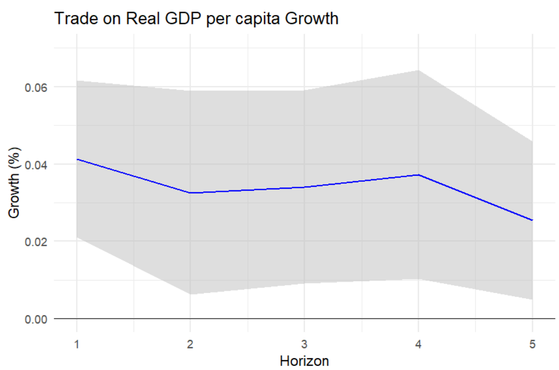
[11] Using the mean GDP, measured in constant US dollars from the World Economic Outlook
[12] All calculations for this cost section can be found in the appendix.



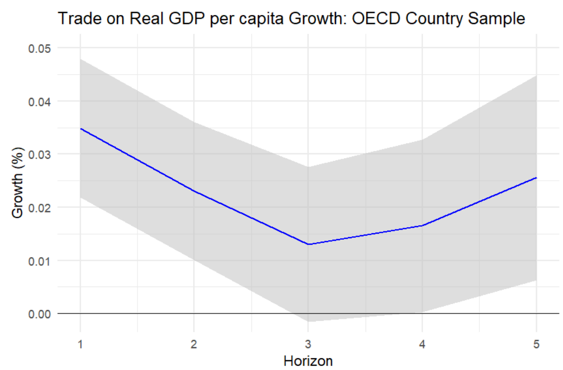
(a) sustainable Trade & real GDP per capita Growth



(b) TLCT & real GDP per capita Growth



(c) Trade & real GDP per capita Growth



(d) Trade & real GDP per capita Growth: OECD

Figure 19: Impacts on real GDP per capita Growth

same calculation, real GDP per capita decreases by $233.73 over the five year horizon. To compare these numbers to an increase in general trade for the SSA, a one-standard deviation increase in trade as a % of GDP corresponds to $9.40 billion increase. This corresponds to an increase in real GDP per capita by $99.86 over the five year horizon. For the OECD sample, a one-standard deviation increase in trade as a % of GDP corresponds to $620.42 billion increase. This calculates to a $534.92 increase in real GDP per capita.

As a result of these calculations, it finds that a one-standard deviation increase in sustainable trade may result in a $100-$233 decrease in per capita GDP. However, increasing trade by a standard deviation increases per capita GDP by less than $100. Since the increase in trade is about 30 times more than the increase in sustainable trade, it shows that an increase in sustainable trade would have more of a negative effect on GDP growth than an increase in trade would have a positive effect. However, this does not necessarily mean that sustainable trade would be detrimental for growth as the results were mostly insignificant.

In summary, sustainable trade may have the potential to reduce the number of deaths related to air pollution and sustainable trade have negative but insignificant effects on real GDP growth.

7 Sustainable Practices Index

7.1 Data and Methodology

We construct a novel Sustainable Practices Index (SPI) for Sub-Saharan Africa to encourage discussions around assessing and promoting sustainable economic practices in international trade. This index region-specific tool offers immediate and actionable policy insights by standardizing, ranking, and comparing sustainable trade practices in SSA. The index will serve as a benchmark for countries in SSA to map their performance across key components and identify leaders/laggards under a common framework.

We consider four key variables for the construction of the index - environmental taxes, climate change policies, renewable energy adoption, and carbon stock – which are crucial indicators of how countries are integrating environmental considerations into their economic activities. These four variables were chosen because of their relation to environmental outcomes, and we were able to find complete data for a sub-sample of Sub-Saharan Africa. As usual, our country sample limits our data availability. As global awareness of environmental issues grows, such an index plays a crucial role in shaping coordinated global policies and strategies aimed at reducing the environmental impact of trade activities. Assessing the sustainability of trade policies and practices can foster regional cooperation that is instrumental in SSA to address trans-boundary environmental challenges such as climate change, deforestation, and biodiversity loss.

Environmental taxes (% of GDP), as sourced from the IMF Climate Change Dashboard, are a tax imposed on a physical unit (or a proxy of it) of something that has a proven, specific, negative impact on the environment. A SPI that incorporates environmental taxes can incentivize stricter action to meet regional standards by countries that are lagging in implementation. By doing so, it encourages a reduction in environmental footprint, leading to more sustainable production and trade practices. It also helps internalize the environmental costs of trade, ensuring that prices more accurately reflect the true cost of goods and services.

Climate change policies are policies aimed at benefiting the environment as sourced from the Climate Policy Database. We record it as a stock variable to capture the total number of such policies in-force as they can have lasting consequences beyond the year of enactment. By highlighting best practices and identifying areas for improvement, the index coordinates regional efforts in SSA to implement more climate change policies. This, in turn, promotes trade practices that are more resilient to climate impacts and aligned with global climate goals.

Renewable energy underscores the importance of transitioning from fossil fuels to cleaner energy sources. We measure it as sum of renewable energy use from wind, solar, bio, and hydro energy sourced from the IMF Climate Change Dashboard. As each value of renewable energy has its own unit, we standardize their values between 0 and 100 and aggregate. A higher number will reflect that a country uses more renewable energy. This encourages both public and private sectors to increase their adoption of renewable energy, reducing reliance on non-renewable resources and lowering greenhouse gas emissions. The SPI thus plays a crucial role in promoting energy security and sustainability in global trade.

Carbon stock refers to the amount of carbon stored in forests, soils, oceans, and other ecosystems. A SPI that factors in carbon stock emphasizes the importance of preserving and enhancing these natural carbon sinks. By recognizing carbon stock as a critical component of environmental health, the index encourages countries to implement trade practices that protect and restore these ecosystems. This is particularly important in combating deforestation, land degradation, and other activities that release stored carbon into the atmosphere.

To construct the Sustainable Practices Index, we begin by rescaling the respective values of each component to lie between 0 and 100. The highest value receives a score of 100 and the least favorable value is scored as 0. This methodology follows the Hinrich IMD Sustainable Trade Index. This scoring allows us to compare the four indicators that are measured and computed differently. Then, we run a principal component analysis to gather the correct weights for each variable. Table 5 shows the proportion of variance for each principal component. We decided to use the first 3 components in order to capture about 90% of the total variance. The first principal component weighs heavily on renewable energy and carbon stock, and the second weighs more heavily on climate change policies and environmental taxes. We construct the index by adding each weighted principal component, and rescaling the final values between 0 and 100.

Table 5: Principal Component Analysis

PC	Proportion of Variance
1	0.381
2	0.3216
3	0.2081
Total	0.9107

There are 14 countries included in the SPI: Cabo Verde, Cameroon, Democratic Republic of the Congo, Cote d'Ivoire, Eswatini, Ghana, Kenya, Mali, Niger, Rwanda, Sierra Leone, South Africa, Togo, and Uganda. The data runs from 2001-2020 at an annual frequency. While there is not a lot of overlap of countries between the index and the sample used for sustainable trade analysis due to limited data availability across indicators in SSA, we appreciate the diverse dynamic between sustainable practices and environmental outcomes explored in this section.

Additionally, there was not enough overlap with the GCB Net CO2 emissions country sample. As a replacement, we use the World Bank's CO2 emissions taken from the Climate Watch Historical GHG Emissions defined as the amount of CO2 in metric tons per capita. Rather than looking at CO2 production in trade, this allows us a more general look at pollution values. In our analysis, we use the log difference. Figure 20 shows the median value of CO2 emissions among our country sample each year. This figure similarly parallels Figure 3b. Notice how in the year 2020, the percentage change of CO2 emissions plummeted due to production halts caused by COVID.

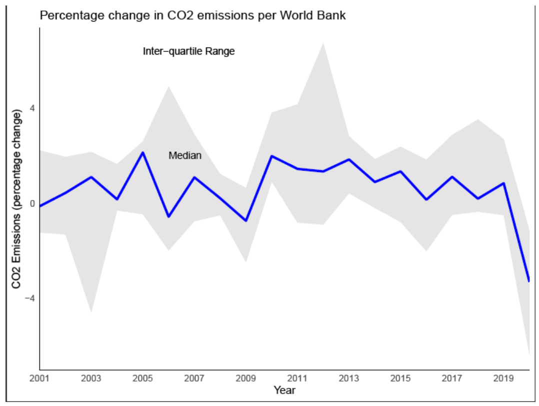


Figure 20: WB Median Log Difference CO2 Emissions

This section uses the same controls as in the previous analysis: GDP per capita growth, population growth, and urbanization growth. The summary statistics for the SPI, the dependent variables, and the controls are in table **??**. In table **??**, we list the 2020 SPI values for each country from largest to smallest. Since renewable energy is so highly weighted, our top contributors, like the Democratic Republic of the Congo, Cabo Verde, Cote d'Ivoire, Cameroon, and Niger, have high amounts of renewable energy. Surprisingly, South Africa is at the bottom. While they have the highest number of active climate change policies, they lack in the other components, and over the data sample period, have fallen lower and lower in the rank.

Table 6: SPI Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Med	Max
GPI	280	46.70	19.34	0	43.36	100
GFN EF	280	0.95	3.54	−22.38	0.88	25.67
WB CO2	280	0.73	4.36	−21.60	0.59	24.33
GBD PM2.5	280	−0.15	4.89	−22.98	−0.36	22.87

This section continues to use linear local projection analysis. The model estimates the cumulative impulse response functions from a 1-standard deviation increase in the SPI. The estimation similarly models equation 1, however, the dependent variable is replaced by the SPI.

Table 7: Sustainable Practices Index Year 2020 Values

Country	Index Value
Dem. Rep. of Congo	99.17
Cabo Verde	68.32
Cote d'Ivoire	64.04
Cameroon	62.66
Niger	61.91
Togo	45.22
Uganda	42.33
Mali	39.43
Rwanda	39.09
Ghana	37.78
Sierra Leone	34.77
Kenya	33.09
Eswatini	29.78
South Africa	2.32

7.2 Effect of Sustainable Practices on Environmental Outcomes

Figures 21-23 show the results for shocking Sustainable Practices Index on environmental outcomes. We find that an increase in sustainable practices leads to a reduction in the ecological footprint, with the most significant decrease occurring after four years, reflecting a 0.03% decline. The impact of sustainable practices on carbon emissions is notably stronger where we see a sharper and significant decline in emissions of 1.5% after three years. sustainable practices have a smaller impact and delayed, nonetheless beneficial, impact on PM2.5 levels showing a decline of 0.05% after four years.

Consistent with sustainable trade, sustainable practices have mitigating effects on environmental outcomes with peak declines after three to four years.

The medium-term reductions in harmful environmental outcomes resulting from sustainable practices can be explained by several interconnected mechanisms. Environmental taxes incentivize industries to adopt cleaner technologies by internalizing the environmental costs of production, leading to reduced greenhouse gas emissions and ecological footprints over time (Ghazouani et al., 2021). Similarly, climate policies, particularly carbon pricing and emissions trading systems, create financial incentives for industries and consumers to lower their carbon footprint, fostering a shift toward sustainable economic activities (Kohlscheen et al., 2024). Renewable energy adoption further reinforces this transition by reducing reliance on fossil fuels, which significantly decreases carbon emissions and improves air quality (Attanayake et al., 2024).

Preserving and enhancing carbon stocks, such as forests and soils, also plays a critical role in sequestering carbon dioxide and combating climate change. Policies that protect these natural carbon sinks maintain ecological balance and reduce atmospheric CO levels. Collectively, these mechanisms demonstrate why the positive impacts of sustainable practices emerge more significantly in the medium term, as structural changes and behavioral shifts take time to materialize into measurable environmental benefits.

SPIGFN.png

Figure 21: SPI and GFN Ecological Footprint

SPIWB.png

Figure 22: SPI and WB CO2 Emissions

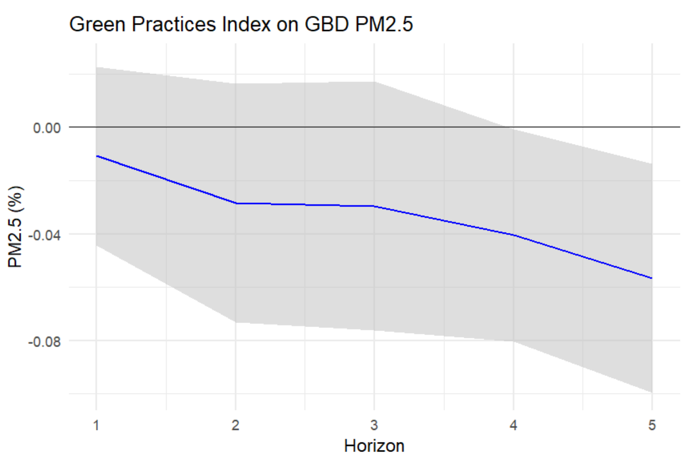


Figure 23: SPI and GBD PM2.5

8 Conclusion and Policy Implications

The paper is the first to attempt to establish a relationship between sustainable trade and environmental outcomes in Sub-Saharan Africa. Using local projections analysis, the study finds that increasing sustainable trade leads to improved environmental outcomes, with effects peaking after 3-5 years. This long-term relationship can be attributed to the time required to develop the necessary infrastructure and workforce to effectively utilize sustainable goods. sustainable trade mitigates environmental impacts by reducing carbon emissions, promoting the sustainable use of natural resources, and encouraging the adoption of clean technologies. These mitigation effects are significantly higher than those associated with general trade. By promoting such practices, sustainable trade helps offset the environmental impact of trade-related economic activities.

Furthermore, this paper addresses the comparison of sustainable trade on a global scale, finding that sustainable trade has a greater impact on environmental outcomes in the SSA region. The implications on economic welfare for sustainable trade are be measured by showing that the number of deaths caused by air pollution decreases and the effect of GDP per capita is negative.

Moreover, the paper constructs the sustainable Practices Index to quantify and standardize sustainable policies across the region. The results show that increasing sustainable practices reduces negative environmental outcomes, with the effects peaking after 3-4 years. This finding aligns with the sustainable trade analysis and has important policy implications.

To strengthen sustainable trade policies in the region, the paper recommends reducing barriers to sustainable goods and imposing restrictions on high carbon-emitting products. Identifying sustainable and non-sustainable goods at the border is essential for reducing trade barriers for environmentally friendly products, yet it remains a complex challenge. Harmonized System (HS) codes provide a foundational framework for classifying goods, including categories for renewable energy technologies and pollution control equipment. The Environmental Goods Agreement (EGA) negotiations offer a complementary approach, with a preliminary list of sustainable goods such as wind turbines, solar panels, and energy-efficient appliances. These tools, while not universally adopted, provide a starting point for countries to classify and promote sustainable goods in trade.

To make this recommendation actionable, countries should leverage existing frameworks while tailoring them to local priorities. Aligning with HS codes and the EGA list ensures consistency, while national or regional initiatives can fill gaps where international classifications fall short. Capacity building at customs, including training officials and deploying technologies like AI-driven classification systems, can improve accuracy in identifying sustainable goods. Additionally, embedding sustainable goods provisions into regional trade agreements can harmonize classifications and facilitate cooperation. By building on these strategies, countries can make trade in sustainable goods a key driver of sustainable development while addressing current limitations in identification and classification mechanisms.

Given the significant role of renewable energy in driving positive environmental outcomes, the paper also calls for increased investment in renewable energy by expanding related policies and infrastructure. It also stresses the need to improve climate change policies and enhance efforts to reduce environmental footprints.

One other critical policy recommendations emerging from the results is the implementation of carbon taxation. Carbon taxes are an effective tool for internalizing the environmental costs of carbon emissions by directly targeting the primary source of greenhouse gases. Our analysis shows that sustainable trade is closely linked to the reduction of carbon emissions, and a well-structured carbon tax would complement this by incentivizing industries to adopt cleaner technologies and shift toward sustainable practices. Carbon taxation would also generate revenue that can be reinvested into sustainable infrastructure and renewable energy projects, further enhancing the long-term benefits of sustainable trade. By placing a price on carbon emissions, governments can effectively discourage high-emitting activities and create a more level playing field for sustainable alternatives.

Additionally, the implementation of carbon taxes, in alignment with the findings of this paper, would help further reduce emissions by making carbon-intensive goods less competitive compared to sustainable alternatives. This policy would directly address the environmental externalities associated with both domestic and international trade in Sub-Saharan Africa. In this way, carbon taxation would reinforce the positive effects of sustainable trade, accelerating the shift toward a low-carbon economy in the region.

Furthermore, the paper urges the strengthening of environmental taxation, either by introducing new taxes or increasing existing ones. Most importantly, it advocates for greater regional collaboration among Sub-Saharan African countries to harmonize sustainable trade practices. This would prevent companies from relocating within the continent to areas with more lenient environmental regulations, which could undermine overall efforts to address climate vulnerabilities. The idea of sustainable trade and its impacts on environmental outcomes and economic growth, especially low-income countries, is widely understudied.

The paper provides a novel contribution to the study of the impact of sustainable trade and sustainable practices, as compared to general trade, on environmental outcomes in Sub-Saharan Africa. Future research can expand on our analysis by looking into growth outcomes, evaluating how institutions with more environmental policy stringency may exhibit larger impacts, or analyzing sustainable trade dynamics on a micro level.

References

Ahmed, F., Kousar, S., Pervaiz, A. et al. (2022). Role of sustainable innovation, trade and energy to promote sustainable economic growth: a case of South Asian Nations. Environmental Science and Pollution Research, 29, 6871–6885.

Ali, E. B., Shayanmehr, S., Radmehr, R., Bayitse, R., & Agbozo, E. (2024). Investigating environmental quality among G20 nations: The impacts of environmental goods and low-carbon technologies in mitigating environmental degradation. Geoscience Frontiers, 15(1), 101695.

Antweiler, W., Copeland, B. R., & Taylor, M. S. (2001). Is free trade good for the environment?. American economic review, 91(4), 877-908.

Attanayake, K., Wickramage, I., Samarasinghe, U., Ranmini, Y., Ehalapitiya, S., Jayathilaka, R., & Yapa, S. (2024). Renewable energy as a solution to climate change: Insights from a comprehensive study across nations. Plos one, 19(6), e0299807.

Bekoe, William & Jalloh, Talatu. (2023). Assessing the Economic Implications of Free Trade on Environmental Quality: Empirical Evidence from Africa. Environmental and Resource Economics, 84, 19-36.

Ben Zineb, S. (2019). Impact of Trade in Environmentally Preferable Products and Clean Technologies on Economic Growth and Environmental Quality: Empirical Analysis in Developing Countries and in OECD Countries. Institutions & Transition Economics: Environmental Issues eJournal.

Can, M., Ben Jebli, M., & Brusselaers, J. (2022). Can sustainable trade save the environment? Introducing the sustainable (Trade) Openness Index. Environmental Science and Pollution Research, 29(29), 44091- 44102.

Cherniwchan, Jevan, Copeland, Brian R., & Taylor, M. Scott. (2016) Trade and the environment: New methods, measurements, and results, NBER Working Paper No. 22636.

Cherniwchan, Jevan & Taylor, M. Scott. (2022) International trade and the environment: Three remaining empirical challenges, NBER Working Paper No. 30020.

Copeland, Brian R. & Taylor, M. Scott. (2004). Trade, growth, and the environment. Journal of Economic Literature, 42(1), 7-71.

Dada, James Temitope, Ajide, Folorunsho Monsur, Al-Faryan, Mamdouh Abdulaziz Saleh , & Tabash, Mosab I. (2024). Trade policy and environmental sustainability in Africa: An empirical analysis. Natural Resources Forum. Oxford, UK: Blackwell Publishing Ltd.

Damania, Richard, Fredriksson, Per G., & List, John A. (2003). Trade liberalization, corruption, and environmental policy formation: theory and evidence. Journal of Environmental Economics and Management, 46(3), 490-512.

Duan, Yuwan, Ji, Ting, Lu, Yi & Wang, Siying. (2021). Environmental regulations and international trade: A quantitative economic analysis of world pollution emissions. Journal of Public Economics, 203.

EM-DAT, CRED / UCLouvain, 2024, Brussels, Belgium – www.emdat.be, Accessed on Oct 6, 2024.

Frankel, J. A., & Romer, D. (1999). Trade and Growth. The American Economic Review, 89(3), 379-399.

Ghazouani, A., Jebli, M. B., & Shahzad, U. (2021). Impacts of environmental taxes and technologies on greenhouse gas emissions: contextual evidence from leading emitter European countries. Environmental Science and Pollution Research, 28, 22758-22767.

Global Center on Adaption. (2022). Climate risks in Africa. State and Trend in Adaption Report.

Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American free trade agreement. NBER Working Paper 3914.

Hasna, M. Z., Jaumotte, M. F., Kim, J., Pienknagura, S., & Schwerhoff, G. (2023). sustainable innovation and diffusion: Policies to accelerate them and expected impact on macroeconomic and firm-level performance. International Monetary Fund, SDN/2023/008.

Hu, X., Pollitt, H., Pirie, J., Mercure, J. F., Liu, J., Meng, J., & Tao, S. (2020). The impacts of the trade liberalization of environmental goods on power system and CO2 emissions. Energy Policy, 140, 111173.

Ibrahim, Mansor H., & Law, Siong Hook. (2016). Institutional quality and CO2 emission-trade relations: Evidence from Sub-Saharan Africa. South African Journal of Economics, 84(2).

Ibrahim, Ridwan Lanre & Ajide, Kazeem Bello. (2022). Trade facilitation and environmental quality: Empirical evidence from some selected African countries. Environment, Development and Sustainability, 24, 1282-1312.

Jaramillo, Laura, Aliona Cebotari, Yoro Diallo, Rhea Gupta, Yugo Koshima, Chandana Kularatne, Jeong Dae Lee et al. (2023). Climate challenges in fragile and conflict-affected states. International Monetary Fund, Staff Climate Note 2023/001.

Jorda, Oscar. (2005). Estimation and inference of impulse responses by local projections. American Economic Review, 95(1), 161-182.

Jorda, Oscar and Alan M. Taylor. (2024). Local Projections. Federal Reserve Bank of San Francisco Working Paper 2024-24. https://doi.org/10.24148/wp2024-24.

Kavoussi, R. M. (1984). Export expansion and economic growth: Further empirical evidence. Journal of Development Economics, 14(1), 241-250.

Kim, Dong-Hyeon, Suen, Yu-Bo, & Lin, Shu-Chin. (2019). Carbon dioxide emissions and trade: Evidence from disaggregate trade data. Engery Economic, 78, 13-28.

Kohlscheen, E., Moessner, R., & Takats, E. (2024). Effects of carbon pricing and other climate policies on CO2 emissions. arXiv preprint arXiv:2402.03800.

Lin, Boqiang, Omoju, Oluwasola E., Nwakeze, Ngozi M., Okonkwo, Jennifer U., & Megbowon, Ebenezer T. (2016). Is the environmental Kuznets curve hypothesis a sound basis for environmental policy in Africa? Journal of Cleaner Production, 133, 712-724.

Olaoye, Olugbenga Olaposi, Quadri, Faruq Umar & Olaniyi, Oluwaseun Oladeji (2024). Examining the role of trade on the relationship between environmental quality and energy consumption: Insights from Sub Saharan Africa. Journal of Economics, Management and Trade, 30(6), 16-35.

Onafowora, O. A., & Owoye, O. (1998). Can trade liberalization stimulate economic growth in Africa?. World Development, 26(3), 497-506.

Pienknagura, Samuel. (2024). Trade in low carbon technologies: The role of climate and trade policies. IMF Working Paper, WP/24/75.

Shapiro, Joseph S. (2021). The environmental bias of trade policy. The Quarterly Journal of Economics, 136(2), 831-886.

Shu, Yang, Riti, JS, & Zhang, Kexin. (2024). Trade policy and environmental quality in Africa: Aggregation issues and policy deductions. Journal of Cleaner Production, 447(141217).

Stock, J. H., & Watson, M. W. (2005). Understanding changes in international business cycle dynamics. Journal of the European Economic Association, 3(5), 968-1006.

Tariq, Muhammad, Xu, Yingzhi, Ullah, Kifayat, & Dong, Biying. (2023). Toward low-carbon emissions and sustainable growth for sustainable development in emerging economies: Do sustainable trade openness, eco-innovation, and carbon price matter? Sustainable Development, 32(1), 959-978.

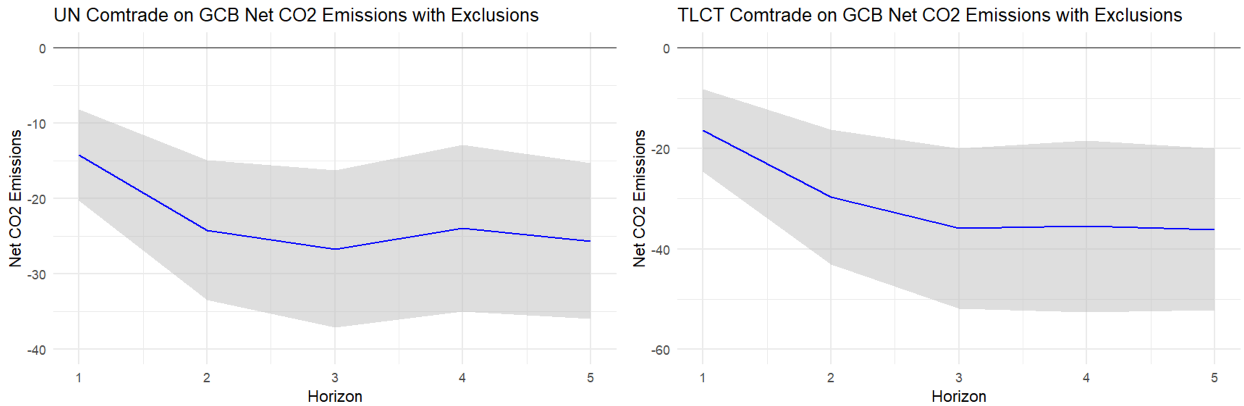
Udeagha, Maxwell Chukwudi & Breitenbach, Marthinus Christoffel. (2022). On the asymmetric effects of trade openness on CO2 emissions in SADC with a nonlinear ARDL approach. Discover Sustainability, 4(1).

US EPA. Basics of Climate Change. https://www.epa.gov/climatechange, Accessed on Oct 6, 2024.

Xu, Xiaoying. (2022). The impact of natural resources on sustainable growth: The role of sustainable trade. Resources Policy, 78.

Zahonogo, P. (2016). Trade and economic growth in developing countries: Evidence from sub-Saharan Africa. Journal of African Trade, 3(1-2), 41-56.

Appendix



(a) UN Comtrade & GCB Net CO2 Emissions

(b) TLCT & GCB Net CO2 Emissions

Figure A1: sustainable Trade on GCB with Exclusions

Section 6 calculations

Figure 19a:

$$0.0092 * 33.66 \text{ billion} = 309.67 \text{ million dollars} \tag{1a.1}$$

$$\text{First year: } 5874.31 * 0.0085 = -49.93 \text{ dollars} \tag{1a.2}$$

$$\text{Second year: } 5874.31 * 0.0070 = 41.12 \text{ dollars} \tag{1a.3}$$

$$\text{Third year: } 5874.31 * 0.0029 = 17.04 \text{ dollars} \tag{1a.4}$$

$$\text{Fourth year: } 5874.31 * 0.0171 = -100.45 \text{ dollars} \tag{1a.5}$$

$$\text{Fifth year: } 5874.31 * 0.0014 = -8.22 \text{ dollars} \tag{1a.6}$$

Figure 19b:

$$0.0052 * 35.28 \text{ billion} = 183.456 \text{ million dollars} \tag{2a.1}$$

$$\text{First year: } 6086.80 * 0.0142 = -86.43 \text{ dollars} \tag{2a.2}$$

$$\text{Second year: } 6086.80 * 0.0123 = 74.87 \text{ dollars} \tag{2a.3}$$

$$\text{Third year: } 6086.80 * 0.003 = 18.26 \text{ dollars} \tag{2a.4}$$

$$\text{Fourth year: } 6086.80 * 0.0289 = -175.91 \text{ dollars} \tag{2a.5}$$

$$\text{Fifth year: } 6086.80 * 0.0106 = -64.52 \text{ dollars} \tag{2a.6}$$

Figure 19c:

$$0.2792 * 33.66 \text{ billion} = 9.40 \text{ billion dollars} \tag{3a.1}$$

$$\text{First year: } 5874.31 * 0.0041 = 24.08 \text{ dollars} \tag{3a.2}$$

$$\text{Second year: } 5874.31 * 0.0033 = 19.39 \text{ dollars} \tag{3a.3}$$

$$\text{Third year: } 5874.31 * 0.0034 = 19.97 \text{ dollars} \tag{3a.4}$$

$$\text{Fourth year: } 5874.31 * 0.0037 = 21.73 \text{ dollars} \tag{3a.5}$$

$$\text{Fifth year: } 5874.31 * 0.0025 = 14.69 \text{ dollars} \tag{3a.6}$$

Figure 19d:

$$0.5523 * 1187.58 \text{ billion} = 620.421 \text{ billion dollars} \tag{4a.1}$$

$$\text{First year: } 46921.68 * 0.0035 = 164.23 \text{ dollars} \tag{4a.2}$$

$$\text{Second year: } 46921.68 * 0.0023 = 107.92 \text{ dollars} \tag{4a.3}$$

$$\text{Third year: } 46921.68 * 0.0013 = 61.00 \text{ dollars} \tag{4a.4}$$

$$\text{Fourth year: } 46921.68 * 0.0017 = 79.77 \text{ dollars} \tag{4a.5}$$

$$\text{Fifth year: } 46921.68 * 0.0026 = 122.00 \text{ dollars} \tag{4a.6}$$

PUBLICATIONS