Volume 6, Issue 2, pp. 47-51, 2022.

International Journal of Scientific Engineering and Science
ISSN (Online): 2456-7361

The Impact of Logistics Performance on Carbon Emission: An Empirical Investigation on African Countries

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Abstract— *The aim of the study is to examine the relationship between logistics and eco-efficiency, as measured by carbon emissions, in the most polluted African countries. The study was carried out in 10 countries, namely South Africa, Egypt, Algeria, Nigeria, Morocco, Libya, Angola, Tunisia, Sudan, Kenya and Ghana, using data from 2007 to 2020. Logistics efficiency is measured by the Logistics Performance Index (LPI) and carbon emissions by CO_2 (carbon dioxide) emissions per capita using publicly available secondary data published by the "World Bank" and the" Our World in Data database". The analysis is performed using a regression model to see the relationship between the 6 performance variables and CO_2 emissions by using the software R.*

Keywords— *Logistics performance, carbon emission, regression analysis, performance indicators.*

I. Introduction

The growth of globally interlinked production activities and the intensity of global competition have also made logistics a source of strategic competitive advantage for companies at the micro level and at the macro level for countries. Mustra agrees and confirms that well-functioning logistics is the most important element of the national advantage and competitiveness. [1].

Also Increased competitiveness will in turn encourage economic growth.

Another study conducted by the World Bank, stated that logistics represents one of the most important sectors for economic development, where logistics performance affects growth and national development in the first place [2].

However, in the era of sustainable development, if development focuses only on economic aspects, development will not be valued, but should include the three dimensions of sustainable development, namely economy, society and environment. [3]

Social and environmental aspects are now on the agenda of the global community, and responsible and sustainable supply chain management (SCM) is one of the issues to be focused on in this regard [4]. In addition, the World Bank (WB) defines sustainable supply chain as "managing economic, social and environmental impacts", and promoting good governance practices throughout the life cycle of goods and services.

The World Bank also states that the objective of a sustainable supply chain is to create, protect and improve product quality and enhance long-term economi, social and environmental value for all stakeholders involved.

Karaduman said that logistics, as an important sector of supply chain management, is receiving increasing attention because of its role in global trade and the social and environmental impacts it can have. so, the logistics industry is facing enormous pressure to implement carbon management in order to increase the efficiency of logistics activities for economic development and thus reduce the impact on the environment.[3].

II. Literature Review

1. CO_2 Emission

The market is so large and the environmental effects of the logistics sector are receiving increasing attention. So the environmental aspect of sustainability is mainly related to climate change, or in other words, global warming. Global warming is an average increase in temperature due to emissions of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

And because carbon dioxide (CO2) is the most common GHG in terms of the amount released and the total impact on global warming, these GHGs are often measured in carbon dioxide equivalents (CO2-e).[5]

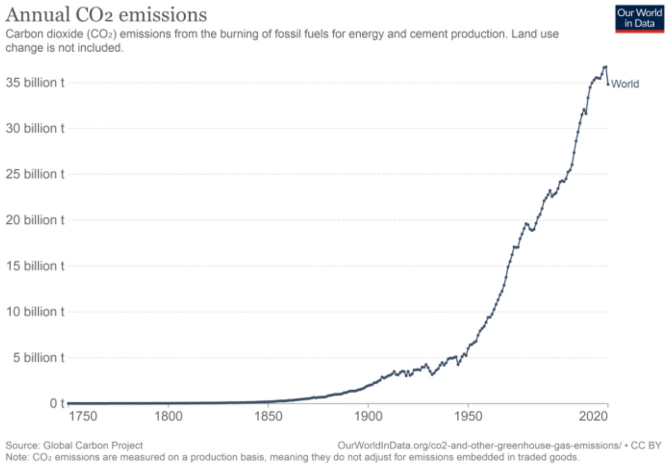


Figure 1: Annual CO_2 emissions in the world

We note that before the industrial revolution, CO_2 emissions were very low. The growth of emissions remained relatively slow until the middle of the 20th century. In 1950, the world was emitting 6 billion tons of CO_2. By 1990, this figure had almost quadrupled to over 22 billion tons. Emissions have continued to rise rapidly; we now emit more than 34 billion tons each year. Emissions growth has slowed in recent years, but they have not yet peaked.

In this study, carbon emissions are CO_2 emissions per capita (metric tons per capita). The site measure of carbon emissions per capita is the total amount of carbon dioxide that is emitted per country as a result of all relevant human activities (production and consumption). The World Bank definition indicates that carbon dioxide emissions are those that come from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during the consumption of solid, liquid and gaseous fuels and the flaring of gas.

2. Logistics Performance Indicator

Since 2007, the Logistics Performance Index (LPI) published by the World Bank has been at the heart of the debate on the role of logistics in economic growth and the policies that support it. Composite indices, such as the LPI, help policy makers by providing them with data on which to base their decisions.

The WB defines the LPI as the perception of a country's logistics efficiency in terms of customs operations, transport infrastructure, shipping, logistics services, traceability of goods and on-time delivery. The measurement of logistics performance is done with a value of 1 to 5, where a value of indicates the best performance.

LPI is based on a standardized questionnaire and uses statistical techniques to aggregate the data into a single index that can be used to compare countries, regions and incomes [6] IPL's data collection is based on a structured online survey of logistics professionals, from multinational freight forwarders to major express carriers, who are responsible for transporting goods around the world. Their choice of delivery routes and gateways influences decisions about production locations, supplier selection, and target markets. Nearly 1,000 logistics professionals from 125 countries participated in the 2013 survey.

The first part of the LPI survey consists of a questionnaire in which each randomly selected respondent rates eight foreign markets on six logistics performance indicators. The eight countries are chosen based on the most important export and import markets in the respondent's country.[6]

The six indicators are:

- The efficiency of customs and border clearance ("Customs").
- The quality of trade and transportation infrastructure ("Infrastructure").
- The ease of organizing shipments at competitive prices ("Ease of Organizing Shipments").
- The competence and quality of logistics services: trucking, shipping and customs brokerage ("Quality of Logistics Services").
- Ability to track and trace shipments ("Tracking and tracing").
- Planned or expected delivery times ("On-time delivery")

The International LPI is constructed from these six indicators using PCA, a standard statistical technique used to reduce the dimensionality of a dataset. The standardized scores of each of the original six indicators are multiplied by their component loadings and then summed.

3. Logistics Performance and Carbon Emission

The importance of sustainable logistics activities is gaining increasing attention, especially as logistics activities have an impact on the transport sector, which is considered to be the largest contributor to greenhouse gas emissions in the world. The number of companies adopting green or sustainable logistics is also increasing. However, their effectiveness needs to be assessed. A study is therefore needed to assess the link between logistics efficiency and carbon emissions.

Karaduman focused his research on the relationship between logistics and carbon performance. The research was conducted in the Balkan countries using the LPI[3]. Karaduman's research found a significant and positive correlation between carbon and LPI, meaning that Balkan countries with higher LPI scores tend to have lower carbon emissions.

Liu also used performance indicators to analyze the impact of logistics performance on environmental degradation.

These data were collected in 42 Asian countries for the period from 2007 to 2017 [7] The significant relationship is found between LPI and environmental degradation In particular, international shipping, the pillar of LPI, significantly reduces CO2 emissions while the pillar of logistics punctuality leads to an increase in CO2 emissions. Based on the research results, other pillars of LPI, such as location and tracking, service quality and competence, infrastructure quality, and customs efficiency are also closely related to the environment in various sub-regions of Asia.

The study by Mariano et al. is to assess the effectiveness of the relationship between transport logistics performance as measured by the LPI and CO2 emissions from the transport sector using the DEA method and to construct a low-carbon logistics performance index (LPI). [8] The results show that the best performing countries measured by the low-carbon IPL are Germany, Japan, Benin, Togo and the United States.while the most developed countries are Luxembourg, Honduras, Ireland and Lebanon.

In another study combining CO2 emissions, LPI and oil consumption from the transportation sector, Lu et al. developed an Environmental Logistics Performance Index (ELPI) to assess the overall performance of green transportation and logistics practices in 112 countries. [9] Their results show a strong correlation between the ELPI and the IPL - income and region are closely related to country performance.

The study concludes that, in general, countries with a high LPI score perform better in terms of green transport. In this case, improvements in green logistics and transport performance can be achieved through effective compliance with environmental regulations and the promotion of clean energy use.

Santosa conducted a study to understand the relationship between logistics performance and carbon emissions in ASEAN countries and the results indicate that the infrastructure is quite environmentally friendly and has proven its ability to

Volume 6, Issue 2, pp. 47-51, 2022.
ISSN (Online): 2456-7361

reduce carbon emissions. However, the international shipping indicator is, on the contrary, positively related to carbon emissions. The other 4 indicators are not significant enough to be linked to carbon emissions [10].

4. Hypothesis

Many studies have been conducted to investigate the relationship between logistic performance and carbon emissions with different variables. Research by Liu et al; Karaduman et al; Mariano et al; and Larson concluded that there is a significant relationship between carbon emissions and logistics performance. [3], [7], [8]

Karaduman found a significant and positive relationship between the two variables in Balkan countries, implying that higher LPIs contribute to lower carbon emissions.[3]. Research by Liu et al. shows that there is a significant relationship between logistics performance and environmental degradation [7]

In particular, international shipping, one of the pillars of the IPL, significantly reduces CO_2 emissions, while the speed of the logistics pillar increases CO_2 emissions in 42 Asian countries.

In this study we analyze the relationship between CO_2 and LPI In 10 African countries, in this sense we developed the followed hypothesis:

H0: The efficiency of customs and border clearance affects carbon emissions in the African countries

H1: The quality of trade and transportation infrastructure affects Carbon emissions in the African countries

H2: The ease of organizing shipments at competitive prices affects Carbon emissions in the African countries

H3: The competence and quality of logistics services affects Carbon emissions in the African countries

H4: The Ability to track and trace shipments affects Carbon emissions in the African countries

III. Research Methodology

This study examines the relationship between the indicators of logistics performance and carbon emissions in the ten most polluting countries in Africa: South Africa, Egypt, Algeria, Algeria, Nigeria, Morocco, Libya, Angola, Angola, Tunisia, Sudan, Kenya and Ghana.

The data used are secondary data obtained from the World Bank and Our World in data, including the Logistics Performance Index {LP} with its six indicators, carbon emissions and control variable data, i.e. CO2 emissions and control variable data, i.e. trade and urban population for the period 2007-2018.

To examine the relationship between LPI and carbon emissions in the mentioned countries, the panel data analysis method was used and the software R, followed by a regression study following the model as follows:

$$Cit = \alpha + \beta 1LPIit + \beta 2POPit + \beta 3COMc + INDit + \varepsilon it$$

And by adding the 6 indicators of the LPI in equation (1) , the final version of the equation is :

$$Cit = \alpha + \beta 1LTRit + \beta 2LQCit + \beta 3LISit + \beta 4LCTit + \beta 5LTIMEit + \beta 6LINFit + \beta 6LINFit + \varepsilon it$$

Variables:

C = Carbon emission per capita
LTR : tracking and tracing(1=low to 5=high)
LQC : services quality and competence (1=low to 5=high)
LIS : International shipments(1=low to 5=high)
LCT : customs (1=low to 5=high)
LTIME : timeliness(1=low to 5=high)
LINF : Infrastructure of logistics (1=low to 5=high)
POP : Urban population
TR : Trade (% du PIB)
IND : industrial value added
ε = terme d'erreur

IV. Results & Discussions

4.1 Summary Statistics

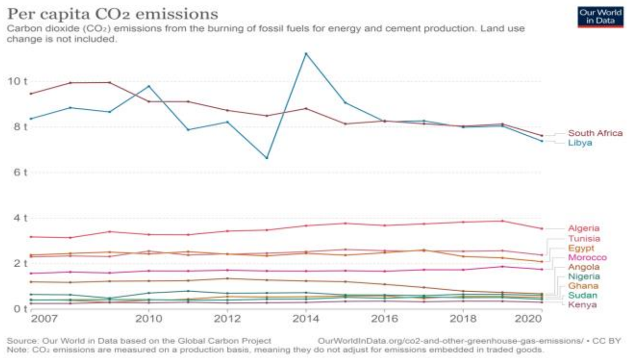
The first table reports the summary statistics of the independent and dependent variables.

From the table 1, the score of LPI Score is ranging from 1.933 to 3.245, with the mean value of 2.384 on the other side, Co2 emissions are ranging from 0.2977 to 8.5728 with the mean value of 2.9397.

TABLE 1: descriptive statistics

```
> summary(Dataset)
 Country.Code       co2              LPI.SCORE
 AGO      :1    Min.    :0.2977    Min.    :1.933
 DZA      :1    1st Qu.:0.7690    1st Qu.:2.111
 EGY      :1    Median :2.1130    Median :2.308
 KEN      :1    Mean    :2.9397    Mean    :2.384
 LBY      :1    3rd Qu.:3.2392    3rd Qu.:2.574
 MAR      :1    Max.    :8.5728    Max.    :3.245
 (Other):4
```

The following figure presents the carbon emissions data for the selected African countries:



The figure shows that in 2020, the country that emits the most carbon is South Africa with 7.62 tons, Libya with 7.38 T, followed by Algeria (3.53 T), then Tunisia, Egypt and Morocco with 1.75 T. Kenya has the lowest co2 emissions.

IJSES

International Journal of Scientific Engineering and Science

Volume 6, Issue 2, pp. 47-51, 2022. ISSN (Online): 2456-7361

4.2 Correlation Test

TABLE 2: Correlation test

```
> rcorr.adjust(Dataset[,c("co2","CUSTOMS","INFRASTRUCTURE","INT.SHIPMENT","LPI.SCORE","LPI.SERVICES","LPI.TIME",
+   "TRACKING","TRADE.GDP","URBN.POP")], type="pearson", use="complete")

 Pearson correlations:
```

	co2	CUSTOMS	INFRASTRUCTURE	INT.SHIPMENT	LPI.SCORE	LPI.SERVICES	LPI.TIME	TRACKING	TRADE.GDP	URBN.POP
co2	1.0000	0.4337	0.9699	0.3201	-0.3141	0.4136	0.4205	0.4059	0.4543	0.4728
CUSTOMS	0.4337	1.0000	0.4648	0.9163	0.0042	0.8623	0.9288	0.8535	0.0622	0.9279
INFRASTRUCTURE	0.9699	0.4648	1.0000	0.4134	-0.2993	0.5206	0.5064	0.4996	0.3369	0.5585
INT.SHIPMENT	0.3201	0.9163	0.4134	1.0000	0.1351	0.9212	0.9863	0.9560	-0.0857	0.9813
LPI.SCORE	-0.3141	0.0042	-0.2993	0.1351	1.0000	-0.1633	0.0214	-0.0558	0.3189	0.0632
LPI.SERVICES	0.4136	0.8623	0.5206	0.9212	-0.1633	1.0000	0.9353	0.9212	-0.2946	0.9351
LPI.TIME	0.4205	0.9288	0.5064	0.9863	0.0214	0.9353	1.0000	0.9785	-0.0823	0.9939
TRACKING	0.4059	0.8535	0.4996	0.9560	-0.0558	0.9212	0.9785	1.0000	-0.1596	0.9616
TRADE.GDP	0.4543	0.0622	0.3369	-0.0857	0.3189	-0.2946	-0.0823	-0.1596	1.0000	-0.0392
URBN.POP	0.4728	0.9279	0.5585	0.9813	0.0632	0.9351	0.9939	0.9616	-0.0392	1.0000

TABLE 3: Pearson value

Pairwise two-sided p-values:

	co2	CUSTOMS	INFRASTRUCTURE	INT.SHIPMENT	LPI.SCORE	LPI.SERVICES	LPI.TIME	TRACKING	TRADE.GDP	URBN.POP
co2		0.2105	<.0001	0.3672	0.3768	0.2347	0.2262	0.2444	0.1872	0.1676
CUSTOMS	0.2105		0.1759	0.0002	0.9908	0.0013	0.0001	0.0017	0.8644	0.0001
INFRASTRUCTURE	<.0001	0.1759		0.2350	0.4008	0.1229	0.1353	0.1415	0.3411	0.0933
INT.SHIPMENT	0.3672	0.0002	0.2350		0.7099	0.0002	<.0001	<.0001	0.8140	<.0001
LPI.SCORE	0.3768	0.9908	0.4008	0.7099		0.6521	0.9533	0.8784	0.3691	0.8624
LPI.SERVICES	0.2347	0.0013	0.1229	0.0002	0.6521		<.0001	0.0002	0.4087	<.0001
LPI.TIME	0.2262	0.0001	0.1353	<.0001	0.9533	<.0001		<.0001	0.8211	<.0001
TRACKING	0.2444	0.0017	0.1415	<.0001	0.8784	0.0002	<.0001		0.6596	<.0001
TRADE.GDP	0.1872	0.8644	0.3411	0.8140	0.3691	0.4087	0.8211	0.6596		0.9145
URBN.POP	0.1676	0.0001	0.0933	<.0001	0.8624	<.0001	<.0001	<.0001	0.9145	

We can conclude from the tables that there' is a significant strong correlation at 0.001 with r = 0.9863 level between the co2 emissions and the indicator of the quality of transport and infrastructure, also a strong positive correlation between the performance of international shipment and the timeliness and tracking respect. However, there is no relationship between the other variables chosen and the emission of CO_2.

Though, correlation analysis can be misleading and does not show ceteris paribus effect of LPI indicators on CO_2 Emissions. It is possible that there was a change in the nature of the relationship between LPI and $lnCO_2$ after controlling for some observable factors such as LPOP, and TRADE.

TABLE 4: Correlation between co_2 and Infrastructure

```
> with(Dataset, cor.test(co2, INFRASTRUCTURE, alternative=
> with(Dataset, cor.test(co2, INFRASTRUCTURE, alternative=

        Pearson's product-moment correlation

data:  co2 and INFRASTRUCTURE
t = 11.259, df = 8, p-value = 0.000003478
alternative hypothesis: true correlation is not equal to (
95 percent confidence interval:
 0.8738764 0.9930708
sample estimates:
      cor
0.9698669
```

As we can see in the table 4, the co_2 emissions increase with the quality of infrastructure as (ports, railroads, roads, information technology) in the selected African countries.

4.3 Regression Test

TABLE 5: Regression tests

```
Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)      -2.4804     2.1487  -1.154  0.33196
CUSTOMS           4.7172     3.3185   1.421  0.25030
INFRASTRUCTURE    2.3423     0.3214   7.287  0.00533 **
INT.SHIPMENT     -0.9155     6.6898  -0.137  0.89981
LPI.SERVICES     -1.6113     1.9380  -0.831  0.46672
LPI.TIME         -6.4028    13.0800  -0.490  0.65804
TRACKING          3.8128     5.7376   0.665  0.55386
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.8154 on 3 degrees of freedom
Multiple R-squared:  0.9757, Adjusted R-squared:  0.927
F-statistic: 20.04 on 6 and 3 DF,  p-value: 0.01613
```

The outputs table shows that the adjusted R of our model is 0,927 with the R^2 =0,9757 that means the linear regression explains 97 % of the variance in the data, the P value is 0. 016, it means that the test is highly significant thus we can assume that there is a siginificant relationship between the variables in our model.

However , we conclude that the only variable that affects the environment and especially the CO_2 emission in the 10 african countries is the quality of infrastructure and transport, and These results are in line with the analysis of Liu in central Asia [11], all the other variables are not significant.

From an economic sense, with a positive slope of 2, 34, shows that each unit increase in the infrastructure will lead to 2,34 units of the infrastructure.

The results indicate that the impact of the indicators of logistics performance on co2 emissions changes from one country to another and from one continent to another, and that there are many other variables involved

Our study has shown that the variable that affects the CO_2 emission is the quality of transport and infrastructure in the African countries chooses: South Africa, Egypt, Algeria. Morocco, Libya, Angola, Tunisia, Sudan, Kenya.

V. Conclusion

To realize the 3 dimensions of sustainable development; economic, social and environmental, The world should react not only to the economic aspect but for the environment protection and the climate change as well.

The climate change is one of the challenges that face the world, and the major cause of climate change is the carbon emission.

The Aim of this study is to analyze the relationship between the 6 indicators of logistics performance, named, the ability to track, the quality of logistics services, the international shipments, clearance process, time delivery, and the quality of transport and infrastructure, and carbon emissions per capita, in 10 African countries: South Africa, Egypt, Algeria. Morocco, Libya, Angola, Tunisia, Sudan, Kenya,

By using the open data developed by the World Bank.

Several studies, have analyzed the analysis of the relationship between these variables, and most have found that the best performing countries tend to have lower emissions.

However our study of the LPI indicators shows that there's only one indicator that is significantly related to carbon emissions, namely infrastructure, while the other indicators are not related to CO_2 emissions, so the African countries should develop policies to make infrastructure more environmentally friendly.

This study is based on 10 African countries, in this sense the data is limited, we suggest to analyze the relationship between LPI and carbon emissions in other African countries to extend the results

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