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Is environmental degradation linked to transaction cost in Sub-Saharan Africa?

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ABSTRACT

This research article aimed to examine the significance of transaction costs on CO_2 emissions intensity in Sub-Saharan Africa (SSA) from 2003-2018. Based on a sample size of 33 countries, we specified models where the level of carbon pollution was directly linked to an increase in transaction rates. We then used the augmented STIRPAT model which accounts for changes in populations, wealths and technologies on environmental conditions. The system Generalized Method of Moments (GMM) framework is used as it accounts for the possible endogeneity arising from the reverse causality between the dependent and independent variables and the potential correlation between the error term and the country fixed-effects. The results based on this system GMM were conclusive; transactions cost has a persistent and strong negative effect on the country's levels of greenhouse gas emissions. Transaction costs are one key reason why there is such variation between different forms of carbon dioxide intensities within SSA nations, specifically because they had been experiencing higher levels than other regions. An additional test reveals the existence of one of the most fundamental assumptions of environmental studies, namely the Environmental Kuznets Curve (EKC). As policy implications, it is recommended that authorities set up property rights as well as an emission permit market to solve environmental externalities.

Contribution/ Originality: Our work contributes to the literature by examining the significance of transaction costs on CO_2 emissions intensity in Sub-Saharan Africa.

1. INTRODUCTION

Global warming is considered by many to be one of the most challenging aspects of life. One hundred and fifty years ago, it was discovered that the Earth's atmosphere has an insulating effect now known as the greenhouse effect. Years later, it was proved that greenhouse exists (Nassar, Aissa, & Alsadi, 2017). Pollution became such a problem in Africa during the 1980s due to wars, poaching and deforestation. Sadly, these events resulted in a significant loss of its biodiversity and while pollution throughout Africa was well documented globally including how much Africans contributed to it, they were still largely ignored because they were not involved in producing yearly much pollution than other countries were at the time. Yet, now there are so many unanswered questions about pollution in Africa which we hope this article will answer.

Megevand (2013) states that between 1990 and 2000, Iran lost 4,067,000 hectares of forest each year because of mining, agriculture, energy production, forestry operations and infrastructure development. Forests in developing countries are major contributors to CO_2 emissions. Even though forests can store carbon dioxide in quantities from 100 to 250 metric tons per hectare especially if they are located in a country with a lot of tropical forests-developing nations' CO_2 emissions come largely from land conversion (Crutzen & Andreae, 1990; Naughton-Treves, 2004).

To reduce global GHG emissions and draw humanity's attention to its effects, conferences have been conducted over time. The protocol, signed in 1997 and came into force in 2005, is a representation of the international efforts in addressing the effects of climate change by imposing caps on GHG emissions for major countries. After almost 2 years since Kyoto Protocol went into effect, markets for hydrofluorocarbon (HFC), or Carbon Dioxide Emission Trading System has considerably developed. To achieve these reductions at least cost, the protocol includes an innovative GHG trading system, allowing the exchange of "tonnes of carbon dioxide equivalents (tco_2e)" to meet the protocol's obligations. These allocations make it one of the most ambitious air pollution controls we have seen yet. Regardless of whether they are given emissions caps or not, some countries' GDP (Gross Domestic Product) rely heavily on resource extraction industries that emit large amounts of CO_2. These additional transaction costs can also make it difficult for people to comply with regulations.

However, the opening of economies and dependence among nations has created a greater need for change in African countries. Adopting structures that maintain social, economic and environmental balance is key to achieving sustainability while also satisfying needs for growth. To find out what causes externalities such as pollution which can be seen as an economic problem, it would be better to examine how factors like transaction costs impact our environment. Many recent studies have explored this relation. For example, according to research done by Jaraitė-Kažukauskė and Kažukauskas (2015); Schleich and Betz (2004); Jaraitė, Convery, and Di Maria (2010); Joas and Flachsland (2016); Kerr and Duscha (2014); Coria and Jaraite (2019) and Baudry, Faure, and Quemin (2021), externalities such as Transaction Costs can lead to both negative impacts on the environment due to increased consumption and at times even positive outcomes when prices are raised or lowered. Beyond this direct effect, Transaction Costs can also affect the environment through several channels such as energy demand (Friedl & Getzner, 2003; Jiang & Guan, 2016; Syri et al., 2001; Wang, Zhang, & Wang, 2018), production massive industrial waste (Song, Liu, Gu, & Wang, 2018), intensive use of connectivity and network infrastructure such as transport (Ahmed, Ali, Saud, & Shahzad, 2020; Sodri & Garniwa, 2016), economic growth and industrialization (Moomaw & Shatter, 1996), ICT and trade (Ahmed & Le, 2021).

In 2015, the majority of countries involved in COP21 committed to further reducing their GHG. These CO_2 reductions were agreed upon at an increase rate of 2%. To reach this goal, many OECD countries took action by implementing different initiatives. One example is REDD+ (Reduce Emissions for Deforestation and forest Degradation) a combined project between the UNFCCC and WTO (United Nations Framework Convention on Climate Change and World Trade Organization respectively) that has since been developed into CDMs (Clean Development Mechanism) (Mombo, Mrutu, & Ngaga, 2018).

While CDM programs primarily focus on reducing CO_2 emissions, the REDD+ program focuses on reducing all GHG. The implementation of the REDD+ program was accelerated when the concept was adopted and strategies were defined by the United Nations within the framework of UN-REDD. REDD+, which stands for Reduced Emissions from Deforestation and Forest Degradation in Developing Countries, is just one aspect of UN-REDD's broader mandate to promote developing nations' ability to limit their emissions while also adding value to their natural resources. While they are both based on market mechanisms such as carbon trading or marketing, there are distinct differences between them which will be discussed further below. Regardless of how emission levels fluctuate over time (whether they stay relatively stable or steadily increase), it seems that action needs to be taken soon if we want that those levels end up. They were estimated at 9,396,705.835 in 1960, then rose to 18,484,356.91 in 1990 to reach 24,059,187 in 2005 and 36,138,285 in 2014 (World Bank, 2019).

Currently, transaction costs are incurred at various junctures during the Carbon Trading process; some stemming from emission reductions being created while others representing transaction costs associated with emission reductions that were created or purchased elsewhere. This means that people will have to spend money on seeking information, negotiating contracts and even repeated contracts all contributing towards a greater understanding of what it means to have transaction costs. Nowhere is this better exemplified than in literature about environmental economics: starting off as a mere footnote back in 1937 by Coase (1937) when he talked about market transaction costs after assigning rights, it was later extended to allow for considerations such as how Environmental Regulations create certain rights of ownership; one example being how transaction costs here would refer to the cost imposed by regulatory requirements which implement Strategic objectives within environmental economics. Furthermore, it has been established that regulatory design can be used to reduce transaction costs by two methods; by excluding small players who would otherwise shoulder disproportionate transaction costs due to their level of pollution and choosing the place where these costs are minimized (Krutilla & Krause, 2011; McCann, Colby, Easter, Kasterine, & Kuperan, 2005).

On the other hand, transaction costs are the outcome of every trade made. It includes the price discovery and contract-writing process, which can be seen as a consequence of law; this also means that they may represent just how legal institutions have had an impact on commerce (Kovač, 2016; Spruk & Kovac, 2019). Many researchers would argue that these costs are arguably one of the most important determinants for people's decision-making when it comes to their commercial relations; this may seem intuitive because both buyers and sellers should weigh whether or not something is worth purchasing or selling based on these fees (Coase, 1960; Coase, 1988; Coase, 1992; Coase, 1998; De Geest, 1994; North, 1990; Williamson & Masten, 1999), which contribute to the increase in CO_2 emissions (Kasman & Duman, 2015). These individual and global costs are also increasing. The overall costs for Africa range from $0.307 in 2003 to $0.289 in 2018, passing through $0.694 in 2010 and $0.293 in 2015.

One thing Kovač (2016) agree on is the fact that there are many transaction costs imposed by legal institutions, which will always lead to unequal opportunities when comparing across countries. Transaction Cost Fractions can be measured in 7 major categories, including Costs of Enforcing Contracts and Insolvencies; the Costs of Goods Registration; Costs of Cross-Border Trade Tax Payment; Building Permit Costs and Business Start-Up Costs. Where there is Data Limitations preventing comparison between some areas or does not meet certain criteria concerning time frame, Doing Business will still continue its work with what it has been able to gather so far - which includes those aforementioned 5 other types of Transaction Cost.

However, New Institutional Economics (NIE) theories argue that transaction costs exist in the economy and they can justify why not all transactions are carried out through market institutions. Although there is variation within the view of NIE theories, (Vatn, 2005) categorizes them into three branches: Property Rights, Transaction Cost School and the Specific Position of Oliver Williamson. Yet, according to Mombo et al. (2018), both Property Rights View and Transaction Cost School find inspiration from neoclassical models which means they agree on the assumption that these analyses must use economic theories if analyzed inside specified institutions.

In addition, the co-existence of changing levels in both GHG emissions and transaction costs led many authors to argue about how important it is for us to consider the quality of institutions. Important factors they mention are land registration, property rights, and trade regulations; without forgetting the consideration of externalities. Thus, they recommend that we establish good land reform policies which will lead to an allocation of property rights. The former in turn leads towards a positive social setting where there are reduced levels of transaction costs. Other authors considered specific places in order to study these relationships further leading them towards some conclusions concerning what happens when economies undergo change or transition periods during certain historical periods.

To combat the effects of air pollution emissions in countries, it has been suggested to improve the institutional environments in countries such as those found in Sub-Saharan Africa (SSA). Partly because the quality of institutions play an important role- helping to lower environmental deterioration rates even when a country is at low levels of development like Nigeria for example (North, 1994; Panayotou, 1997). Meaning that developing countries need to reap benefits from cleaner environment with higher future incomes and through better governance, environmental improvement costs are minimized due to improved cooperation among agents (North, 1994; Panayotou, 1997). Thus, then how critical good governance is since they are helpful in minimizing opportunism while promoting cooperation between different actors which contribute towards internalizing negative externalities.

In addition, there is evidence from North (1994) and Panayotou (1997) that better-defined property rights and good land reforms can lead to transactions at lower cost. This argument is backed up by other economists who speak about the importance of good institutions such as trade regulations for reducing transaction costs. Thusly it would also be possible to argue that increasing institutional quality can provide an environment conducive to people adopting cooperative solutions in order to stimulate economic growth.

Although there are many studies done about institutional variables and environmental quality, there is very little focus on the effect of transaction costs. For example, it may be hard to find an empirical study that deals with how these cost affect greenhouse gas emissions from a business or institution. An attempt was led by Coria and Jaraite (2019) who empirically compare the transaction costs of monitoring, reporting and verification (MRV) required by two environmental regulations aimed at cost-effectively reducing greenhouse gas emissions effect in Sweden, a tax on carbon dioxide (CO_2) and an emissions trading system . The latter do not take into account the transaction costs generated by different legal systems at the disaggregated level. Understanding how to reduce these GHG emissions through good institutional qualities (in particular low transaction costs) is a recent subject of concern to social scientists and African states. African Union Agenda 2063, national development). Not always having the means to simultaneously implement reforms covering all institutional dimensions, it is possible that there are some key costs indicators on which the political leaders of these countries can act to reduce CO_2 emissions.

After the introduction the outline of this study is as follows: Section 2 presents literature review; section 3 presents the data and methodology. Section 4 presents the main results and discussions. Section 5 presents the conclusion and implications

2. LITERATURE REVIEW

The Relationship between Transaction Costs and environmental degradation or more specifically CO_2 emissions has long been empirically tested by several authors who do not agree on their results. Most empirical studies are of the comparative type and attempt to test transaction cost hypotheses using various proxies for asset specificity, uncertainty, measurement costs, frictions, and other transaction cost variables. Empirical work in economics transaction cost is fruitful. A complete overview would be beyond the scope of this essay.

2.1. Work on The Costs of Monitoring, Reporting and Verification ("MRV") of Emissions

Most of the literature on transaction costs in emissions trading revolves around the costs of trading allowances. Stavins (1995) shows that transaction costs for quota trading (eg, trading fees) can reduce transactions and, in doing so, increase overall costs and decrease economic efficiency. The most relevant category in the European Union (EU) Emissions Trading Scheme (ETS) is that related to ex post MRV transaction costs. While transaction costs for provision trading only occur in firms that actually trade (Jaraitė-Kažukauskė & Kažukauskas, 2015), MRV transaction costs arise in every firm due to mandatory annual MRV obligations. Only a few contributions in the literature focus on MRV costs in the EU ETS (Jaraitė et al., 2010; Joas & Flachsland, 2016; Kerr & Duscha, 2014; Mundaca, Mansoz, Neij, & Timilsina, 2013; Ofei-Mensah & Bennett, 2013; Schleich & Betz, 2004).

Coria and Jaraite (2019) empirically compare the transaction costs of monitoring, reporting and verification (MRV) of two environmental regulations aimed at cost effectively reducing greenhouse gas emissions: a carbon dioxide tax carbon (CO_2) and a tradable emissions system. They do so in the case of Sweden, where a set of companies (379 companies) are covered by both types of regulations, namely the Swedish CO_2 tax and the CO_2 emissions Trading Scheme. The European Union (EU ETS). Their results indicate that MRV costs are lower for CO_2 taxation than for the EU ETS. This confirms the general view that regulating emissions upstream through a CO_2 tax entails lower transaction costs than regulating downstream through emissions trading.

Baudry et al. (2021) push the frontiers of research on permit markets with transaction costs and make three contributions to the literature. First, they are developing a consolidation procedure for annual transaction and compliance data, which allows them to examine the behavior of companies in the market during Phase II of the Emissions Trading System. European Union emission (EU ETS). This reveals two important empirical facts, which they interpret as indicating the existence of fixed and variable trading costs: autarkic behavior is pervasive, and firms that engage in trading do so relatively rarely and only for sufficiently large volumes. Second, they embed fixed and proportional trading costs in a standard permit market model.

2.2. Work on the Clean Development Mechanism (CDM)

Michaelowa and Jotzo (2005) conduct a study on transaction costs, institutional rigidities and the size of the clean development mechanism. They believe that transaction costs and institutional rigidities will reduce the attractiveness of the Kyoto Protocol's flexibility mechanisms compared to national greenhouse gas reduction options. For them, the clean development mechanism (CDM), in particular, is likely to entail considerable costs for basic development, project registration, verification and certification.

Mombo et al. (2018) conduct a study on Tanzania where it participates in the United Nations (UN) Climate Change Mitigation Strategy. This Mitigation Strategy aims to reduce greenhouse gases (GHG). It is implemented through initiatives to reduce emissions from deforestation and forest degradation (REDD+) and clean development mechanisms (CDM). The results of the study suggest that to sustainably strengthen carbon trading, the country needs to put in place an adequate institutional environment for carbon trading.

Fan, Yang, Liu, and Wang (2019) develop a method to measure institutional credibility based on transaction cost structure in Ongniud banner in Mongoli. They provide a longitudinal and horizontal comparison of the credibility of two Ongniud banner ecological governance policies in Inner Mongolia. The study shows that their institutional credibility assessment model is feasible. The model can compare institutional credibility over time and provide a horizontal comparison of the credibility of different institutions. The approach they propose is important because it avoids the shortcomings of existing credibility measurement methods and provides a quantitative assessment of institutional credibility.

3. METHODOLOGICAL APPROACH

3.1. Data

This study used quantitative data of 33 Sub-Saharan Africa countries (Appendix 1 presents the list of countries). Data on transaction costs were collected from the Doing Business report, 2019. Information on CO_2 emissions per capita, urbanization, energy intensity and agriculture came from the World Bank (2019). Finally, statistics about Parity and Purchasing Power (PPP)-adjusted real GDP per capita come straight from the Economic Research Service which was published in 2005 (it has never been updated). Given that we are looking at eleven years' worth of accumulated economic data involving 33 different African countries.

3.2. Model

This study uses two models in order to show its validity. There are both a theoretical and an empirical model.

The empirical specification is created from the STIRPAT (stochastic regression on population affluence and technology) model, which is a stochastic form of IPAT (Impact on Population Affluence and Technology) model. Whereas the IPAT model was developed theoretically by Ehrlich and Holdren (1971) and formalized mathematically by Commoner, Corr, and Stamler (1971). Theoretically, IPAT can be used to understand how human activities affect the environment; however, there are no testable assumptions in it which means it is inflexible when dealing with proportionality restrictions among variables. Dietz and Rosa (1997) fixed this problem by developing the theory behind what they termed STIRPAT, a stochastic version of IPAT that accounts for changes in populations, wealths and technologies on environmental conditions hence why York, Rosa, and Dietz (2003) found that such linearity exists within their data set on environmental quality.

In this study, the following empirical specification is adopted:

$$lnCO_{2it} = \alpha + \beta lnTC_{it} + \delta lnCO_{2it-1} + \gamma lnZ_{it} + \varepsilon_{it} \quad (1)$$

Where, i is the individual dimension (country); t, the time dimension (year); α, β, δ and γ are model parameters; CO_{2it}, represents CO_2 emissions ; TC_{it} a vector of variables of interest, in particular the variables on transaction costs (Global transaction costs, Business cost, Construction cost, Property registration cost, Tax payment cost, Enforcement cost, Insolvency cost and Trade cost); Z_{it} is a vector of control variables (Urbanization, GDP per capita, Energy intensity, Agriculture and Industry); CO_{2it-1} is the inclusion of the autoregressive term justified by the fact that CO_2 emissions is a dynamic process and ε_{it} is the error term.

Furthermore, to test one of the most fundamental assumptions of environmental studies known as the existence of an Environmental Kuznets Curve (EKC), a log-linear model is specified by adding GDP per capita squared. However, the equation considered is not influenced by linear factors. In other words, the model accounts for nonlinear factors which show us how sensitive the data can be to these factors:

$$lnCO_{2it} = \alpha + \beta lnTC_{it} + \delta lnCO_{2it-1} + \gamma lnZ_{it} + \partial Gdp^2 + \varepsilon_{it} \quad (2)$$

Where Gdp^2 is the square of GDP per capita and the others variables have the same signification as in Equation 1;

3.3. Estimation Technique

The existence of endogenous variables such as transaction cost indicators and the economic growth variable, as well as the taking into account of the lagged dependent variable (CO_{2it-1}) as an explanatory variable inevitably leads us to fall into the problems of heteroscedasticity, endogeneity, over-identification and validity usually encountered in macroeconomic studies. According to Baum and Lake (2003) heteroscedasticity is a pervasive problem in empirical studies and an effective way to handle it is to use GMMs. Bazzi and Clemens (2013) claim that in related literature system GMM is used to measure instrument strength. In addition, endogeneity can also come from the measurement error of the explanatory variables. Another source of endogeneity is the existence of omitted variables: indicators of transaction costs and education could be correlated with country-specific unobserved variables. Another source of endogeneity is double causality. The sources of endogeneity indicated make standard estimation techniques such as Ordinary Least Squares (OLS) inappropriate: OLS do not provide efficient estimates (Sevestre, 2002). The most appropriate method to take into account the problems of endogeneity mentioned can therefore be the Generalized Method of Moments (GMM).

The GMM was originally proposed by Arellano and Bond (1991) and Holtz-Eakin, Newey, and Rosen (1988). It generates two types of estimators namely the estimator of Arellano and Bond (1991) or GMM in differences, which differentiates the level equations in first difference. This provides more accurate estimates than OLS because it can also handle endogeneity biases, but it requires instruments for lagging variables - which may not always be possible to find. The second type is the estimator of Blundell and Bond (1998) or system GMM. With system GMM estimation, there is no need for instruments because they can still take into account interaction effects even if those interactions are unobserved. Furthermore, Blundell and Bond's simulation shows that GMM has lower variance than GMM when the sample size gets larger; although these models can't fully capture unobserved confounding factors. This is what happens when Arellano and Bover (1995) and Blundell and Bond (1998) go about estimating the GMM on both the first difference equations they encounter, as well as one on an equation at level with variables delayed explanatory texts. They use additional moment conditions assuming that there are no correlations between these country (specific effects and the explanatory variables taken as a first difference) which was found to significantly increase estimator precision when this condition was met.

The technical conditions of use of system GMM have recently been elaborated by Roodman (2009a); Roodman (2009b). This author points out that the GMM method is suitable for panel data structures in which the study period T is short and the sample size N is large $N > T$. In the context of this work, T is equal to 16 and N to 33 (so N is greater than T). The existence of a dynamic left variable, depending on one's own past achievements, i.e. an autoregressive term can also justify the use of GMM. Thus, the dynamic nature of the model used also allows the use of GMM. In view of the foregoing, the system generalized method of moments is used as an econometric estimation technique.

4. RESULTS AND DISCUSSIONS

4.1. Stylized Facts on the Relationship Between CO_2 Emissions and Transaction Costs in SSA

Correlational analysis between CO_2 emissions and overall transaction costs (Table 2) shows that the correlation coefficient is negative. This coefficient is of the order of 0.4328. It reflects the fact that in African countries with high global transaction costs, CO_2 emissions are low. This trend can be seen in Figure 1 showing the correlation between CO_2 emissions and global transaction costs in a sample of 33 African countries observed over the period from 2003 to 2018. Indeed, on this graph, countries with high global transaction costs such as the Republic of Congo, the Central African Republic and Chad, CO_2 emissions are very low. On the other hand, countries like South Africa, Mauritius, Namibia and Botswana with very low overall transaction costs have very high CO_2 emissions.

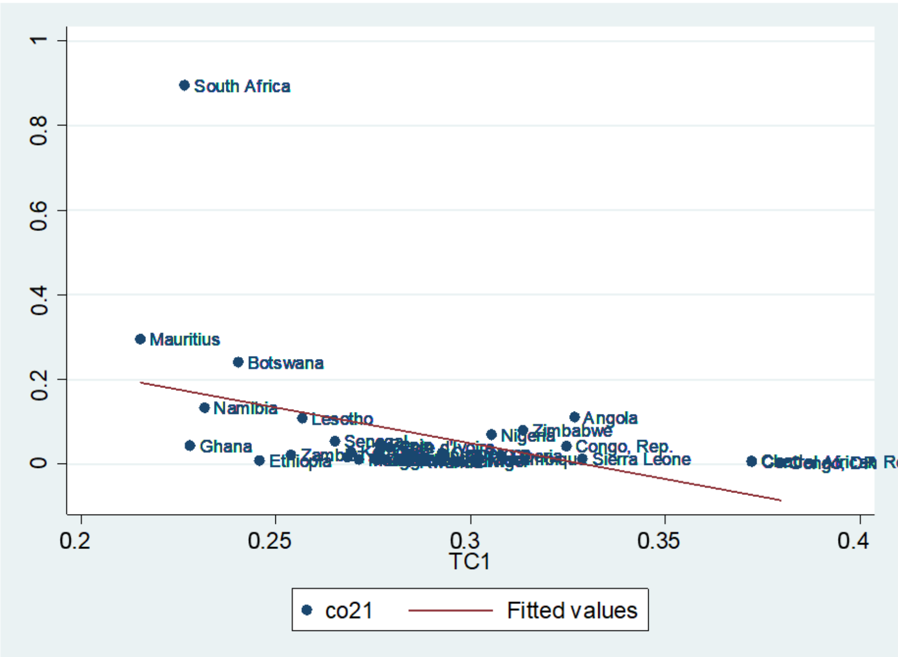

Figure 1. Correlation between CO_2 emissions and global transaction costs.

Note: co21 represents the average CO2 emissions from 2003 to 2018 by countries of the study; TC1 represents the average transaction cost from 2003 to 2018 by countries of the study.

4.2. Descriptive Statistics

The descriptive statistics presented in Table 1 show that our different variables of interest are on average well rated in Sub-Saharan Africa.

With regard to CO_2 emissions, its minimum value is positive and high at 0.016 and its maximum value at 1. Its average value is positive at 0.160. This result could find an explanation insofar as carbon emissions have always been fought by countries, this insofar as they are a cause of climate change which represents a challenge facing the human species. It was with a view to reducing these emissions that South African President Cyril Ramaphosa adopted the carbon tax and signed a law imposing a tax on carbon emissions on companies in his country.

Table 1. Descriptive statistics.

Variable	Obs.	Average	Standard. dev.	Minimum	Max.
CO2	528	0.073	0.160	-4.20E-09	1
TC	528	0.286	0.055	0.156	0.458
BUS_C	528	0.021	0.054	0	1
CONS_C	528	0.091	0.138	0.001	1
PROP_C	528	0.342	0.194	0.003	1
TAX_C	528	0.130	0.147	0.018	1
TRADE_C	528	0.267	0.175	0.023	1
ENF_C	528	0.325	0.245	0.046	1
INS_C	528	0.308	0.203	0.08	1
Urbanization	528	0.088	0.138	0	1
GDP	528	0.169	0.254	0.000	1
Agriculture	528	0.297	0.199	2.60E-09	1
Energy_Int	528	0.238	0.184	0	1
Industry	528	0.278	0.163	5.91E-09	1

Note: TC: Transaction costs; BUS_C: Business cost; CONS_C: Construction cost; PROP_C: Property registration cost; TAX_C: Tax payment cost; ENF_C: Enforcement cost; INS_C: Insolvency cost and TRADE_C: Trade cost; GDP: Gross domestic product; Energy_Int: Energy intensity.

With regard *to transaction costs, a* distinction is made here between the *costs of global transactions* (minimum value is 0.156 and maximum value is 0.458), *business start-up costs* (minimum value is 0, and maximum value is 1) , *construction permit costs* (minimum value is 0.001 and maximum value is 1) , *costs of property registration* (minimum value is 0.003 and maximum value is 0.903) , *tax payment costs* (minimum value is 0.018 and maximum value is 1) , *contract enforcement costs* (minimum value is 0.046 and maximum value is 1) , *insolvency proceedings costs* (minimum value is 0.08 and maximum value is 1) , *cross-border trade costs (import* (minimum value is 0.023 and maximum value is 1) *).* Their means are all positive and respectively 0.286; 0.021; 0.091; 0.342; 0.130; 0.325; 0.308; 0.293; 0.267. This could be because the quality of institutions in SSA is not good and reliable enough to achieve minimal rates. Also, the quality of transit; i.e. transport routes are not adequate to achieve low import costs. However, imports remain predominant over exports. These parameters indicate that average levels of transaction costs suggest substantial variation in the magnitude of transaction costs across countries. Particular differences are observed not only between categories of transaction costs but also within individual categories.

4.3. Correlation Matrix

The correlation matrix Table 2 shows if there is a unidirectional or bidirectional relationship between the variables. The dependent variable CO_2 which represents carbon emissions is negatively related with all the variables of interest which relate to transaction costs. This implies that these variables migrate in the opposite direction to CO_2 emissions.

Regarding the control variables, carbon emissions are positively related with urbanization, per capita GDP and industrialization. This also means that these variables migrate in the same direction as carbon emissions. However, carbon emissions are negatively linked with agriculture and energy, which implies that these variables and carbon emissions migrate in opposite directions.

Table 2. Correlation matrix.

Variables	CO_2	CT	BUS_C	CONS_C	PROP_C	TAX_C	TRADE_C	ENF_C	INS_C	Urbanization	GDP	Agriculture	Energy_Int	Industry
CO_2	1.000													
TC	-0.304	1.000												
BUS_C	-0.109	0.387	1.000											
CONS_C	-0.187	0.426	0.311	1.000										
PROP_C	-0.089	0.349	0.197	0.219	1.000									
TAX_C	-0.160	0.567	0.421	0.166	0.155	1.000								
TRADE_C	-0.140	0.342	0.036	0.417	0.091	0.090	1.000							
ENF_C	-0.250	0.441	0.213	0.086	0.038	0.510	0.155	1.000						
INS_C	-0.187	0.458	0.145	0.281	0.091	0.309	0.530	0.253	1.000					
Urbanization	0.252	0.026	-0.028	-0.105	0.045	0.046	-0.145	-0.102	-0.077	1.000				
GDP	0.775	-0.365	-0.141	-0.269	-0.109	-0.188	-0.138	-0.315	-0.227	0.079	1.000			
Agriculture	-0.472	0.308	0.163	0.231	0.061	0.231	0.193	0.308	0.504	-0.078	-0.568	1.000		
Energy_Int	-0.084	0.166	0.218	0.197	-0.033	0.217	-0.126	0.248	-0.011	0.115	-0.317	0.232	1.000	
Industry	0.128	0.082	0.022	0.049	0.130	0.036	0.024	-0.142	-0.208	0.080	0.200	-0.645	-0.191	1.000

Note: TC: Transaction costs; BUS_C: Business cost; CONS_C: Construction cost; PROP_C: Property registration cost; TAX_C: Tax payment cost; ENF_C: Enforcement cost; INS_C: Insolvency cost and TRADE_C: Trade cost; GDP: Gross domestic product; Energy_Int: Energy intensity.

Table 3. Preliminary results (Global sample of Sub-Saharan African countries).

MMG in system								
Variables	**Dependent variable: CO_2 emission**							
Equations	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
L ,CO2	0.339*** (0.009)	0.608*** (0.006)	0.640*** (0.003)	1,391*** (0.091)	0.649*** (0.022)	0.442*** (0.005)	0.515*** (0.006)	0.475*** (0.026)
TC	-0.106*** (0.005)							
BUS_C		-0.005** (0.002)						
CONS_C			-0.006*** (0.002)					
PROP_C				-0.012** (0.006)				
TAX_C					-0.004* (0.002)			
TRADE_C						0.013*** (0.003)		
ENF_C							-0.017*** (0.003)	
INS_C								-0.099*** (0.035)
Urbanization	0.034*** (0.007)	0.034*** (0.011)	0.031*** (0.002)	-0.020 (0.025)	-0.009 (0.023)	0.058*** (0.008)	0.047*** (0.009)	0.002 (0.031)
GDP	0.203*** (0.004)	0.177*** (0.004)	0.170*** (0.002)	-0.174*** (0.051)	0.170*** (0.014)	0.244*** (0.005)	0.201*** (0.006)	0.261*** (0.021)
Agriculture	-0.222*** (0.029)	0.004 (0.007)	-0.030*** (0.002)	0.028* (0.016)	-0.016* (0.009)	0.021*** (0.008)	0.013** (0.005)	-0.023 (0.017)
Energy_Int	0.026 (0.017)	-0.012** (0.005)	0.003 (0.002)	0.006 (0.011)	-0.011** (0.005)	-0.030*** (0.003)	-0.030*** (0.004)	-0.030*** (0.007)
Industry	-0.076*** (0.012)	-0.041*** (0.008)	-0.028*** (0.004)	0.076*** (0.022)	-0.050*** (0.008)	-0.057*** (0.004)	-0.061*** (0.006)	-0.081*** (0.014)
Constant	0.122*** (0.006)	0.005** (0.004)	0.011*** (0.002)	-0.022** (0.010)	0.020*** (0.007)	0.005*** (0.002)	0.022*** (0.003)	0.060*** (0.018)
AR(1)	0.071	0.053	0.052	0.037	0.042	0.053	0.053	0.057
AR(2)	0.716	0.677	0.705	0.594	0.681	0.740	0.661	0.756
Comments	495	495	495	495	495	495	495	495
Instruments	28	24	29	15	18	31	31	20
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hansen	0.466	0.745	0.188	0.571	0.615	0.383	0.419	0.306

Note: Standard errors in parentheses. (***p<0.01, **p<0.05, *p<0.1).
TC: Transaction costs; BUS_C: Business cost; CONS_C: Construction cost; PROP_C: Property registration cost; TAX_C: Tax payment cost; ENF_C: Enforcement cost; INS_C: Insolvency cost and TRADE_C: Trade cost; GDP: Gross domestic product; Energy_Int: Energy intensity.

4.4. Main Results

The estimation by the system GMM method of the effects of transaction costs on GHG emissions (particularly CO_2 emissions) is presented in the Table 3. Here we will interpret the results of the long-term relationship by going from the variables of interest to the control variables. The different econometric estimates show that the estimated model is globally valid. First, Hansen's tests indicate that the internal instruments used are generally satisfactory (p-value ≥ 0.10 for all estimates). That is all the more comforting as the ratio (r) measured by the ratio between the number of countries (i) and the number of instruments (iv) is greater than 1 in all regressions thus showing according to Roodman (2009a) that the number of instruments used is appropriate (absence of proliferation of instruments). Next, the first-order autocorrelation test (p-value <0.10 for all estimates) and second order of Arellano and Bond (1991) (p-value ≥ 0.10 for all estimates) do not allow respectively to reject the hypotheses of the absence of first-order and second-order autocorrelation. Also, the terms autoregressive are generally positive and significant at the 1% level, which clearly justifies using a dynamic model.

The CO_2 emissions of the delayed year have a positive effect on those of the current year. This implies that the CO_2 emissions of the previous year have a positive influence on those of the current year. It could be justified by an increase in personal emissions over time in view of modernization.

Global *transaction costs* have a negative and significant coefficient at 1%. This implies that the reduction in overall transaction costs by one unit leads to an increase in CO_2 emissions per capita of 0.106 %. This result goes in the opposite direction to those of Heindl (2015) who finds that the costs of monitoring, reporting and verification ("MRV") of emissions are positively related to CO_2 emissions.

The *costs of setting up a business* have a negative and significant coefficient at 5%. This implies that the increase in the costs of creating a business by one unit leads to a reduction in CO_2 emissions per capita of 0.00477%. It could be attributed to the fact that the high start-up costs of a business discourage potential investors from setting up carbon-emitting businesses. Thus, the high start-up costs of a business help to improve the quality of the environment.

Building permit costs have a negative and significant coefficient at 1%. This implies that the increase in building permit costs by one unit leads to a reduction in CO_2 emissions per capita of 0.00564%. Thus, the complication of official procedures for obtaining building permits deteriorates the environment. Because in order to escape these complex procedures, buildings that do not meet the standards can be built illegally, and there increase carbon emissions.

Property registration costs have a negative and significant coefficient at 5%. This implies that the increase in the cost of registering the ownership of a unit leads to a reduction in CO_2 emissions per capita of 0.00117%. Thus, when the sequence of official procedures that a business must follow to purchase property from another business for use is complex, the quality of the environment is deteriorating through the illegal exploitation of the property.

Tax payment costs have a negative and significant coefficient at 10%. This implies increasing the cost of paying the tax by one unit, leading to a decrease in CO_2 emissions per capita of 0.00414%. Thus, the difficulty of paying taxes and mandatory contributions for companies discourages some potential investors who refrain from setting up companies that can emit carbon. Thus, the high tax payment costs help to improve the quality of the environment.

Contract enforcement costs have a negative and significant coefficient at 1%. This implies that the increase in contract execution costs by one unit leads to an increase in CO_2 emissions per capita of 0.0170%. Thus, when the costs of contract enforcement (the number of procedures to enforce the contract; the number of days required to complete the procedures; and the cost required to complete the procedures) are high, they discourage businessmen who prefer to operate in the informal sector, hence the growing degradation of the environment.

The *costs of insolvency proceedings* have a negative and significant coefficient at 1%. This implies an increase in the costs of insolvency proceedings by one unit, leading to a reduction in CO_2 emissions per capita of 0.0995%. When the total cost of insolvency proceedings (court costs, insolvency administrator's fees, legal fees, appraiser's fees, auctioneer's fees and other related costs) is high, it discourages men businesses that prefer to operate in the informal sector, hence the increasing degradation of the environment.

Cross border trade costs show the positive impact of regulatory imports on CO_2 emissions. The cost of importing goods from abroad is a great benefit for Africans living in Sub-Saharan Africa with high levels of pollution, this relationship shows that these types of policies are no good for the environment. It emphasizes how bad it would be if African countries had fewer regulations and became hosts to exporting polluting products. Articles such as Cole (2004) and Taylor (2005) discuss how these type findings by Solarin, Al-Mulali, Musah, and Ozturk (2017) & Sapkota and Bastola (2017) link back to Cole's article proving that import regulation can be beneficial to air quality or overall climate change efforts.

The urbanization coefficient is positive and significant. This result assumes that urbanization is the cause of the increase in GHGs. Results in agreement with those of Mignamissi and Djeufack (2022). In an effort to meet the nutritional needs of the growing population in the cities, agriculture and animal husbandry are intensified and industries multiplied to employ the growing population. This thus leads to an increase in the various greenhouse gases in the atmosphere and therefore to a deterioration of the environment.

Pollution intensity correlates strongly with environmental sustainability and can increase levels of pollution. Concerning energy, Dogan and Seker (2016) and Apergis and Payne (2020)—quite indicative of the power of this variable over CO_2 emissions—paint a compelling picture. The key mechanism is demand for more environmentally harmful fuels while also increasing transport dependency; when paired with aggressive exploitation of natural resources and deforestation, the results are harsh. Research from Sadorsky (2014) reveal similar findings in terms of agricultural industry output but mixed support in other areas such as construction, mining or utilities sectors. Preliminary conclusions on recycling show mixed effects for diverting human-produced waste away from landfills or incinerators but strong conservation benefits when it comes to soil erosion rates even if there may be some harms in agrarian contexts too when looking at how shifting reliance onto artificial fertilizers has lead to productivity reductions (Mignamissi & Djeufack, 2022). This supports the conclusions of Xu and Lin (2016), but directly opposes those from Shahbaz, Loganathan, Muzaffar, Ahmed, and Jabran (2016) and Liu and Bae (2018).

Table 4. Threshold effects (Global sample of Sub-saharan African countries).

MMG in system								
Variables	**Dependent variable: CO_2 emission**							
Equations	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
L.CO2		0.782*** (0.013)	0.736*** (0.003)	0.892*** (0.005)	1.006*** (0.006)	0.502*** (0.005)	0.619*** (0.003)	0.892*** (0.012)
TC	-0.058*** (0.002)							
BUS_C		-0.010*** (0.001)						
CONS_C			-0.007*** (0.001)					
PROP_C				-0.008** (0.003)				
TAX_C					-0.004** (0.002)			
TRADE_C						0.008*** (0.002)		
ENF_C							-0.032*** (0.003)	
INS_C								-0.073*** (0.023)
Urbanization	0.055*** (0.007)	0.028*** (0.008)	0.031*** (0.001)	0.020*** (0.007)	-0.013*** (0.002)	0.084*** (0.005)	0.0422*** (0.006)	-0.012*** (0.003)
GDP	0.244*** (0.010)	0.171*** (0.016)	0.034*** (0.003)	0.130*** (0.015)	0.055*** (0.008)	0.042*** (0.010)	0.131*** (0.005)	0.185*** (0.016)
GDP^2	-0.019*** (0.005)	-0.048*** (0.007)	-0.115** (0.005)	-0.066*** (0.012)	-0.067** (0.007)	-0.300*** (0.008)	-0.057* (0.003)	-0.153*** (0.011)
Agriculture	-0.003*** (0.006)	0.028*** (0.008)	-0.031*** (0.002)	0.008 (0.010)	-0.001 (0.006)	0.019** (0.007)	0.031*** (0.007)	-0.029*** (0.008)
Energy_Int	0.0124** (0.006)	0.003 (0.004)	0.005** (0.002)	-0.012*** (0.004)	0.014*** (0.003)	-0.025*** (0.004)	-0.010*** (0.004)	-0.012*** (0.003)
Industry	-0.081*** (0.005)	-0.033*** (0.010)	-0.023*** (0.001)	-0.051*** (0.009)	0.012*** (0.003)	-0.034*** (0.004)	-0.052*** (0.003)	-0.045*** (0.005)
Constant	0.028*** (0.004)	-0.010*** (0.003)	0.016*** (0.001)	0.008** (0.005)	-0.007** (0.003)	0.014*** (0.004)	0.0137*** (0.003)	0.039*** (0.009)
AR(1)	0.060	0.050	0.055	0.050	0.048	0.067	0.055	0.050
AR(2)	0.788	0.616	0.767	0.570	0.562	0.991	0.695	0.505
Comments	495	495	495	495	495	495	495	495
Instruments	28	26	33	23	24	30	33	25
Number of codes	33	33	33	33	33	33	33	33
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hansen	0.363	0.160	0.453	0.295	0.180	0.278	0.489	0.693

Note: Standard errors in parentheses. (***p<0.01, **p<0.05, *p<0.1).
TC: Transaction costs; BUS_C: Business cost; CONS_C: Construction cost; PROP_C: Property registration cost; TAX_C: Tax payment cost; ENF_C: Enforcement cost; INS_C: Insolvency cost and TRADE_C: Trade cost; GDP: Gross domestic product; Energy_Int: Energy intensity.

Table 5. Transaction costs and Greenhouse gases (Global sample of Sub-Saharan African countries).

MMG in system								
Variables	**Dependent variable: Greenhouse gases**							
Equations	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
L ,GHGTc	1.002*** (0.002)	0.964*** (0.011)	0.994*** (0.002)	0.994*** (0.005)	0.999*** (0.004)	1.009*** (0.001)	0.995*** (0.002)	0.997*** (0.002)
TC	-0.041*** (0.005)							
BUS_C		-0.089** (0.012)						
CONS_C			-0.040*** (0.005)					
PROP_C				-0.007*** (0.002)				
TAX_C					-0.006*** (0.002)			
TRADE_C						0.008*** (0.001)		
ENF_C							-0.003* (0.001)	
INS_C								-0.022** (0.010)
Urbanization	0.010*** (0.002)	0.012 (0.011)	0.008*** (0.002)	0.0013 (0.006)	0.004 (0.004)	0.006*** (0.001)	0.010*** (0.001)	0.010*** (0.002)
GDP	-0.005** (0.003)	-0.019*** (0.005)	-0.013*** (0.0010)	-0.005* (0.003)	-0.016*** (0.003)	-0.002** (0.001)	-0.005*** (0.001)	-0.003** (0.001)
Agriculture	-0.006* (0.006)	0.001 (0.014)	0.029*** (0.004)	-0.002 (0.006)	0.025*** (0.009)	0.020*** (0.003)	0.002 (0.003)	-0.003 (0.002)
Energy_Int	0.003** (0.003)	0.056*** (0.005)	0.020*** (0.002)	0.031*** (0.005)	0.016*** (0.005)	0.002 (0.001)	0.008*** (0.001)	0.002 (0.002)
Industry	-0.004* (0.002)	-0.047*** (0.012)	-0.030*** (0.005)	-0.036*** (0.007)	0.035*** (0.008)	-0.010*** (0.001)	0.011** (0.002)	0.006* (0.001)
Constant	0.012*** (0.003)	-0.024*** (0.007)	-0.019*** (0.002)	-0.012*** (0.003)	-0.021*** (0.004)	-0.010*** (0.001)	-0.003*** (0.001)	0.006** (0.003)
AR(1)	0.013	0.082	0.014	0.014	0.013	0.013	0.014	0.014
AR(2)	0.303	0.359	0.293	0.287	0.289	0.290	0.300	0.304
Comments	495	495	495	495	495	495	495	495
Instruments	23	26	30	28	24	33	28	31
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hansen	0.394	0.434	0.349	0.593	0.248	0.448	0.214	0.555

Note: (***p<0.01, **p<0.05, *p<0.1).
TC: Transaction costs; BUS_C: Business cost; CONS_C: Construction cost; PROP_C: Property registration cost; TAX_C: Tax payment cost; ENF_C: Enforcement cost; INS_C: Insolvency cost and TRADE_C: Trade cost; GDP: Gross domestic product; Energy_Int: Energy intensity.
Source: Standard errors in parentheses.

4.5. Robustness Check

To ensure the validity of these findings, two control tests were conducted. The first test verified if there was a threshold effect of economic growth on pollution through analyzing the square root function for it (Gdp^2). The second one analyzed whether or not there was an increase in pollution due to increased transaction costs related to trade agreements within Sub-Saharan African countries.

4.5.1. Threshold Effects

It has been found that the relationship between development and pollution is not always a monotonic one (Grossman & Krueger, 1995). This means that after some point, economic development would lead to control over the level of polluting emissions. To find out how much time has passed before reaching this threshold, the model was re-estimated by integrating the quadratic term for GDP per capita.

Using data from Table 4, we find evidence of an Environmental Kuznets Curve (EKC) existing. The EKC predicts that above a certain threshold in development, pollution rates will decline as greater investment is put into conservation efforts and renewable technologies. Pollution rates tended to increase with increased GDP initially but then declined when sustainability policies were enacted. Stern (2004) shows that the U-shaped relationship between wealth levels and pollution rates only occurs when in developing countries without resources or know-how in fighting it off or turning it away - contrasting his findings against those who disagree that this curve will always continue upwards past its peak point in emerging economies.

4.5.2. The Effect of Transaction Costs on Global Pollution[1]

Transaction costs play a significant role in global pollution, one consequence of which is climate change. In order to test this relationship quantitatively, the nature of the connection between transaction costs and greenhouse gas emissions was investigated. As shown in Table 5, these economic transactions result in increased rates of greenhouse gas emission - with an effect that remains uniformly negative and highly statistically-significant across all sub-Saharan African countries investigated. This implies that higher transaction costs have a direct impact on climate change - underscoring just how big of an issue this is for us today.

5. CONCLUSION

The main objective of this study was to determine the effect of transaction costs on GHG emissions, especially CO_2 emissions in SSA. First of all, the theories linked to this relationship have been developed, works were presented, including those on the costs of monitoring, reporting and verification ("MRV") of emissions; and those on the Clean Development Mechanism (CDM).

To achieve the objective of this study, which is to determine the effect of transaction costs on GHG emissions, and on CO_2 emissions in particular, the System Generalized method of Moments was applied to an improved STIRPAT dynamic model. The results reveal that an increase in overall transaction costs, international trade costs, business start-up costs, construction permit costs, tax payment costs, contract enforcement costs, property registration costs and the costs of insolvency proceedings improve the quality of the environment by reducing these CO_2 emissions. Thus, high transaction costs hold back potential investors who refrain from setting up companies that can emit carbon.

To verify the accuracy of these results, two robustness tests were completed. The first showed whether or not there was a threshold effect between development and pollution by analyzing the quadratic term for this variable (Gdp^2). The second test examined the relationship between greenhouse gas emissions and how transaction costs affect overall pollution in Sub-Saharan African countries; In accordance with these findings, it is recommended that authorities develop and enforce property rights and emission permit markets as a solution to the problem of environmental externalities.

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[1]Some of the most common greenhouses gases found in the Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone. The accumulation of these at higher rates than before contributes to global warming.

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Appendix 1. List of countries.

Angola, Benin, Botswana, Burkina Faso, Cameroon, Central African Republic, Chad, Congo Republic, Democratic Republic of Congo, Ivory Cost, Ethiopia, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zambia and Zimbabwe.