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IS ENVIRONMENTAL DEGRADATION LINKED TO TRANSACTION COST IN SUB-SAHARAN AFRICA?

Ngnemadon Ahmed Ali Salim[1], Guedie Bogning Rolly Xavera[2], Tchinda Kengne Ricardo[3], Dzou Pierre Patrick[4] and Nzomo Tcheunta Joseph Christian[5]

[1]*PhD. Student; Institution: University of Dschang-Cameroon; Corresponding E-mail: salim.ahmed2299@yahoo.fr*
[2]*PhD. Student; Institution: University of Dschang-Cameroon; E-mail: rollyguedie@yahoo.fr*
[3]*PhD. Student; Institution: University of Dschang-Cameroon; E-mail: rtchinda1@yahoo.fr*
[4]*PhD. Student, University of Dschang-Cameroun; E-mail: dzoupierrepatrick@yahoo.fr*
[5]*Lecturer at the Faculty of Economics and Management; Center for Research in Economics and Management (CERME); University of Dschang, Cameroon; E-mail: jnzomo@yahoo.fr*

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Abstract: This study seeks to quantify the effect of transaction costs on CO_2 emissions in Sub-Saharan Africa. Based on a sample of 33 countries over the period 2003-2018, we specify and estimate a panel data model using the System Generalized Moments Method (GMG-S). Using an augmented STIRPAT model the results reveal a persistent and robust negative effect of transaction costs on the intensity of CO_2 emissions in these countries. We find that the increase in transaction costs could indeed be a very significant pollution factor in Sub-Saharan Africa , the effect is heterogeneous for another level of pollution. This additional test reveals the existence of one of the most fundamental assumptions of environmental studies namely the existence of an environmental Kuznets curve. We therefore suggest the importance of contractual relationships and indicate their significant effect on the intensity of CO_2 emissions in these countries over time.

Keywords: transaction cost, CO_2 emissions, Sub-Saharan Africa.

Jel Codes*:* D23, P52.

1. INTRODUCTION

Global warming is considered by many to be one of the greatest challenges facing the world today. In the 1800s, Fourier discovered that the Earth's atmosphere provided an insulating effect known from that time as the greenhouse effect. Later, Tyndall, proved that the greenhouse effect exists (Nassar *et al.* 2017). Since the start of its development process in the 1980s, the African continent has been confronted with many cancers, in particular civil wars, poaching, deforestation, which has led to a considerable loss of its biodiversity. Specifically, although widely documented in the global literature, transaction cost drivers of pollution have not been extensively discussed in Africa due to its relatively low participation in polluting activities. Taking an interest in this question is therefore an undeniable opportunity. This is why this article is presented as an important contribution to fill the gap observed in the literature.

Megevand (2013) notes that as a result of mining, agricultural, energy, forestry and infrastructure activities, it lost 4,067,000 hectares of forest each year between 1990 and 2000. In developing countries, the major contributors to greenhouse gas emissions are land conversion, particularly the conversion of forest land to agricultural land. Forests in developing countries, especially those with significant tracts of tropical forest, store large volumes of carbon dioxide (CO2), ranging from 100 to 250 metric tons per hectare (Crutzen and Andreae, 1990; Naughton-Treves , 2004).

In order to reduce these GHG emissions and draw humanity's attention to its effects, conferences have been conducted over time. The protocol, signed in 1997 and entered into force in February 2005, represents an international effort to address the threats of climate change by imposing caps on GHG emissions in major countries. Nearly two years after the entry into force of the Kyoto Protocol, the market for greenhouse gas (GHG) emissions has developed considerably. To achieve these reductions at the lowest cost, the protocol includes an innovative GHG trading system, allowing the trading of "tonnes of carbon dioxide equivalent" to meet the obligations of the protocol. This makes the Protocol one of the most ambitious pollution control systems that had been undertaken. Some countries are therefore required to reduce their GHG emissions, others are not; this depends on the emission rate of each country. The rate fixed by the protocol was 5%. One of the concerns raised by these challenges is that the trading provisions of the treaty will require substantial expenditure, in addition to the technical cost of emission reductions that investors and buyers need to trade these goods. These additional expenses (transaction costs) could undermine the very processes designed to make compliance affordable and ultimately realistic.

However, the increasing openness of economies that leads to strong interdependencies between countries and regions of the world, including the transition to a new development paradigm, imposes the need to change the economic structures of African countries. Following this reasoning, it is relevant to adopt structures that maintain, among other things, the socio-economic and environmental balance. Thus, it is fundamental to be interested in the potential effects of transaction costs on pollution, which is economically understood as an externality. Recent empirical work addressing this issue generally shows that transaction costs affect environmental quality (Jaraitë-Kaþukauskë and Kažukauskas, 2014; Schleich and Betz, 2004; Jaraite et *al*, 2010; Joas and Flachsland, 2014; Kerr and Dusch, 2015; Coria and Jaraite, 2018 and Baudry *et al*, 2020). Beyond this direct effect, the relationship also manifests itself through several channels such as energy demand (Syri *et al.* 2001; Friedl and Getzner 2003; Jiang and Guan 2016; Wang, Zhang, and Wang 2018), production massive industrial waste (Song et *al* . 2018), intensive use of connectivity and network infrastructure such as transport (Sodri and Garniwa 2016; Ahmed, Ali et *al* . 2020), economic growth and industrialization (Moomaw and Shatter 1996), ICT and trade (Ahmed and Le 2021).

In 2015 during COP21, countries committed to further reduce GHG emissions which are the cause of the climate changes encountered. The new rate was set at 2%. To achieve these GHG reduction targets, a number of initiatives have been taken by OECD countries. One of them is implemented within the framework of the REDD+ (''Reduced Emission from Deforestation and Forest Degradation'') and MDP (''Clean Development Mechanism'' in French clean development mechanism) (Mombo *et al.* 2018).

While CDM programs focus more on reducing emissions of all GHGs, the REDD+ program focuses on reducing CO_2 emissions. The implementation of the REDD+ program was accelerated when the concept was adopted and the strategies were defined by the United Nations within the framework of the UN-REDD program. The UN-REDD programs were created in September 2008 to help developing countries build their capacity to reduce their emissions and participate in a future REDD+ mechanism. Both REDD+ and CDM institutions are framed by the same practice of carbon trading/marketing, although each has its specificities, summarized in the following sections. In both cases, the common objective is to reduce emissions to a level that is not harmful to the environment, as required by the Kyoto Protocol. Despite the measures taken to reduce these emissions, global GHG emissions or more precisely CO_2 emissions (kt) are constantly changing. 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 (*WDI* , 2016).

In addition, during the carbon trading process, transaction costs occur at several points. Some arise when emission reductions are created, others affect the tradability of emission reductions that have been created or purchased elsewhere. Transaction costs thus correspond to the costs of seeking information, negotiating contracts, and repeated contracting (Coase, 1937). Much of the literature acknowledges the lack of a generally accepted definition and widespread use of the concept of transaction costs. As Krutilla and Krause (2010) have pointed out, in the field of environmental economics, the term "transaction costs" first appeared in the Coase theorem literature in 1937 to refer to the "market transaction costs" following an assignment of rights. Yet over the years the concept has been applied more broadly to take account of the fact that environmental regulations establish rights of use or quasi-ownership for polluters who are generally qualified and subject to review or a regulatory change. In this context, "transaction costs" refer to the costs of the regulatory requirements implementing the strategic objective. Furthermore, it is recognized that regulatory design can be used to reduce transaction costs by two means: excluding small participants who pay disproportionate transaction costs based on their pollution and choosing the point of obligation that minimizes costs. transactions (Krutilla and Krause 2010; McCann, 2013).

On the other hand, transaction costs capture the costs associated with trading in the market, the cost of price discovery, the costs of writing and executing contracts. They are best understood as the outcomes of legal institutions and capture the costs of using legal institutions, and thus represent the materialization of legal institutions (Kovac & Spruk, 2016, 2019). Many researchers agree that transaction costs are one of the most underlying determinants of trade (Coase 1960, 1988, 1992, 1998, North 1990, De Geest 1994, Williamson 1998, Williamson and Masten 1999, Kovac 2011), which contribute to the increase in CO_2 emissions (Kasman and 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.

Like Kovac & Spruk (2016), the approach used here emphasizes the transaction costs generated by legal institutions imposed on economic exchanges. These transaction costs are also intrinsically revealing since they are common to companies in the same country but differ from one country to another. The transaction cost fraction is measured by exploiting seven main categories reflecting sub-categories of firm-level transaction costs: cost of enforcing contracts, cost of insolvency proceedings, cost of registering goods; the costs of cross-border trade; tax payment costs; building permit costs; and business start-up costs. Although the broader range of transaction costs encompasses additional categories such as the cost of obtaining credit, the cost of electricity and the costs of hiring workers, data limitations and the time frame of reports *Doing Business* prohibits the construction of comparative time series for these three additional categories.

However, New Institutional Economies (NIE) theories consider that transaction costs are ubiquitous in the economy and can explain the fact that not all transactions are carried out in market institutions (Vatn, 2005). Although there are some variations within the NEI theoretical framework, Vatn (2005) groups them into three sub-branches: the property rights view, the transaction cost school and the specific position of Oliver Williamson . However, Vatn argues that all of these groups are grounded in the idea that institutions matter in all economic analysis and that they are all heavily inspired by the neoclassical model, which means they agree on the fact that these economic analyzes within the specified institutions must use economic theories (Mombo *et al.* 2018).

In addition, the joint changes in GHG emissions and transaction costs lead some authors to demonstrate the importance of measures of the quality of institutions in this relationship. They thus insist on the notions of land register, property rights and trade regulation; this without forgetting to mention the notion of externality. They thus recommend the establishment of good land reforms which could lead to an attribution of property rights. The latter in turn, well defined, lead to an optimal situation in society, and therefore a reduction in transaction costs. Also, other authors have considered specific areas to conduct the study on the relationship in order to draw conclusions.

To control the effect of air pollution emissions in a country, studies have suggested that it is important to improve the institutional conditions in countries such as SSA countries. This is partly because the quality of institutions plays an important role. It helps to reduce environmental degradation in a country even if it is in a low income country like Nigeria (Panayotou, 1997; North, 1994). This means that countries should benefit from environmental improvements with higher future income levels because institutional quality can reduce the environmental cost of higher economic growth (Panayotou, 1997; North, 1994). Then the quality of institutions is important because it helps to minimize opportunism, to promote cooperative behavior between agents and to allow agents to internalize externalities.

In addition, the joint changes in GHG emissions and transaction costs lead (Panayotou, 1997; North, 1994) to demonstrate the importance of measures of the quality of institutions in this relationship. They thus insist on the notions of land register, property rights and trade regulation; this without forgetting to mention the notion of externality . They thus recommend the establishment of good land reforms which could lead to an attribution of property rights. The latter in turn, well defined, lead to an optimal situation in society, and therefore a reduction in transaction costs. Thus, improving institutional quality can provide an enabling environment for the adoption of cooperative solutions which, in turn, will help stimulate economic growth.

However, although studies on institutional variables and the quality of the environment are growing, very little has focused on the effects of transaction costs. To our modest knowledge, it is difficult to identify studies that deal empirically with the effect of transaction costs on the quality of the environment (such as the reduction of greenhouse gases such as CO_2 emissions). An attempt was led by Jessica Coria & Jurate Jaraite (2018) 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. greenhouse effect in Sweden, a tax on carbon dioxide (CO2) 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 (SDGs, 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 cost indicators on which the political leaders of these countries can act to reduce CO_2 emissions . Therefore, this work aims to answer the following specific question: *what are the effects of transaction costs on CO_2 emissions in Sub-Saharan Africa? In order words, what are the transaction cost indicators that will reduce CO_2 emissions in SSA?*

To answer this question, the objective is to determine the indicators of transaction costs that reduce CO_2 emissions in SSA. To this end, the hypothesis that the increase in transaction costs would reduce CO_2 emissions in SSA is formulated. In order to verify this hypothesis, Kovac and Spruk's transaction cost indicators (2016) are integrated into the augmented dynamic STIRPAT model. According to this model, good quality institutions reduce CO_2 emissions in SSA and vice versa. This model is estimated in dynamic panel using the Generalized Method of Moments (GMM) in system from annual data of *Doing Business* and *World Development Indicators* (World Bank, 2019) of 33 SSA countries observed over the period from 2003 to 2018.

This article takes into account the following sections. After section 1 which introduces the study, section 2 presents a survey of the existing literature (both theoretical and empirical). Section 3 presents the stylized facts. Section 4 discusses the data and methodology used in this study. Section 5 presents and discusses the results. Section 6 concludes the study.

2. THEORETICAL RELATIONSHIP BETWEEN TRANSACTION COSTS AND CO_2 EMISSION

Environmental issues are at the heart of discussions in this contemporary era in both developing and developed economies (Osabajo *et al.* 2020). This further raises concerns about climate change which mainly results from the emission of greenhouse gases (Balint *et al.* 2017). These environmental problems are, however, linked to the increase in transaction costs. This is how work on this relationship was developed. They relate in particular to property rights, externalities and emission permit markets.

2.1. Transaction Costs and CO_2 Emissions: the Theoretical Foundations

In the field of environmental economics, the term "transaction costs" first appeared in the literature on Coase's theorem (1960). In this context, "transaction costs" are the costs of negotiating following an assignment of rights. Coase (1960) also uses the terminology of "market transaction costs". These transaction costs include ex ante (pre-trade) costs associated with research and negotiation, and ex post (post-trade) monitoring and enforcement costs. Transaction costs are therefore the costs of economic exchange and are the set of research, negotiation and execution costs (Cooter and Ulen, 2008; Goldberg, 1985; Mackaay, 2013; Parisi, 2014). The theoretical relationship between transaction costs and GHG emissions or the environment in general is based on the notions of property rights, externalities and emissions permit market.

2.1.1 Property rights at the heart of the relationship between transaction costs and the environment

Transaction costs are the costs of establishing and maintaining property rights (Allen, 1991a) . When transaction costs are positive, the wealth of trade is generated both through specialization gains and reduced transaction costs, or improved property rights. Various institutions reinforce property rights: business, contracts, families, courts, law and the state. All of these institutions have been interpreted as maximizing wealth net of transaction costs (Allen, 1991b) .

The theory of property rights is related to that of transaction costs. Indeed, if the rights have a zero transaction cost (transferable easily and securely), the economic equilibrium achieved after the allocation of resources is efficient regardless of the initial distribution. But since there are transaction costs, the form of organization of property rights is not irrelevant. Coase (1960) demonstrates this result. It shows that there are positive transaction costs which mean that property rights cannot be perfectly delineated. Indeed, agents have imperfect information on the properties of assets. This imperfection in the information system leads to costs which are assimilated to transaction costs and which are called positive transaction costs.

A legal system that protects private property rights is often the most effective at properly allocating costs and benefits among all parties, provided there is a measurable economic impact for each of them. If these rights are unclear, market failure may occur. Market failure in this case means that a solution that meets the reasonable needs of all parties is not found (Kim and Mahoney, 2005). When property rights are not clearly defined or properly protected, market failure can occur (Coase, 1960). In other words, no solution that meets the needs of all parties involved can be found. The term transaction costs is often thus used in situations where only specific assets are important and in cases where actual transactions take place. Property rights, on the other hand, are terms often used when "rules of the game" or issues of ownership structure are involved (Barzel and Kochin, 1992).

There is nothing wrong with separating transaction costs from property rights per se. But to understand the types of fundamental questions raised by Coase (1960), the dependence between these concepts must be recognized. Also, not recognizing the addiction can lead to faulty thinking. Property rights and transaction costs are two sides of the same coin, and given the correspondence it is redundant to say things like "if we assume zero transaction costs and full property rights". To say that a situation has no transaction cost is to say that property rights are complete. Since choices about goods imply choices about gains from trade, if transaction costs are zero, then the distribution of gains from trade must be determined (Krutilla and Krause, 2010).

If transaction costs are prohibitive, property rights will not be established or maintained and will be void. The converse however, is not necessarily true. If property rights are complete in some situations, there are two possibilities; either transaction costs are zero, or costs may have been incurred to secure property rights simply because the benefits of doing so outweigh the costs (in which case the transaction costs are positive) (Kim and Mahoney, 2002). Moreover, when property rights are zero, transaction costs could also be zero. For example, if a property right could never be established, despite the resources devoted to such an objective, no one would bother to incur the expense of establishing property rights, and the good would remain ownerless. Recognizing that transaction costs are the costs of establishing and maintaining property rights clarifies the relationship between the two concepts (Kim and Mahoney, 2005).

2.1.2. Externalities as an environmental problem of transaction costs

Environmental economics has developed on the basis of a reference economic concept, that of the external effect. It is in terms of externality that is interpreted the nuisance generated by pollution, or more generally by the degradation of natural capital. The resulting loss of well-being is assimilated by economic theory to a loss of utility or satisfaction for economic agents. Arthur Cecil Pigou (1920), gives the following definition of the external effect: "The essence of the phenomenon is that a person A, at the same time that he provides another person B with a specific service for which he receives a payment, procures thereby advantages or disadvantages of such a nature that a payment cannot be imposed on those who benefit from it nor compensation taken for the benefit of those who suffer from it. The effect is perfectly symmetrical and can thus be positive or negative: we speak of external economy if the effect is positive and of external diseconomy if the effect is negative. In terms of environmental economics, it is the negative external effects (external diseconomies) that make it possible to represent the phenomena of nuisance and pollution. The absence of compensation by a payment expresses the non-market character of the economy or the diseconomy. External here means external to the exchange merchant.

It is generally recognized that global warming due to greenhouse gas (GHG) emissions is the worst and also the most worrying of the negative externalities. It is the worst in particular because it is caused by human activity in general; and this is the most worrying because the information about the ecological impact of the actions taken is not kept. This has the consequence of encouraging behavior that goes against the rational choices that could be made by consumers if they had all the information concerning the GHG emissions of the products they consume (santerre, 2013). Private property rights are often at the heart of externalities. Instead of resorting to taxation or regulation to correct negative externalities affecting public goods, Coase advocates the allocation of property rights by the state.

2.1.3 Tradable emissions permit market as a means of internalizing externalities

Carbon emission rights are derived from pollutant emission rights. The American economist Dales (1968) was the first to propose the right to emit pollutants, which allows companies to emit pollutants into the environment by complying with legal regulations. The rights become tradable if the government authorizes their exchange between companies.

IFRIC3 (International Financial Reporting Interpretations Committee Emission Rights) explains the right to issue as follows: Typically, in cap-and-trade systems, a government (or government agency) issues rights (allowances) to participating entities to emit a specified level of emissions. (The government may issue the quotas free of charge or the participant may be required to pay for them). System participants can buy and sell allowances and therefore in many systems there is an active market for allowances. At the end of a given period, participants are required to surrender allowances corresponding to their actual emissions (Bradbury, 2007) .

The Kyoto Protocol advises countries to address the issue of greenhouse gas (GHG) reduction through market mechanisms. GHG emission rights, namely carbon emission rights, are considered tradable goods, which are generally obtained through government allocation and purchase in the market. There are three different views regarding the financial classification of carbon emission rights (Peng *et al.* 2017).

The first view is to classify carbon emission rights as stock goods. The Federal Energy Regulatory Commission (FERC) requires that the classification of carbon emission rights be based on their use by companies (Federal Power Commission, 1973). If the rights are used to offset GHG emissions, they must be recorded as capital goods. Milne, (1996) argued that carbon emission rights must meet the prerequisites to qualify as capital goods.

The second view is to classify carbon emission rights as intangible assets. Since carbon emission rights are obtained through free government allocation or purchase and are expected to generate economic revenue, they are a type of intangible asset. After extensive consultation, the International Financial Reporting Interpretations Committee (IFRIC 2003) concluded that carbon emission rights should be confirmed as intangible assets and accounted for by measuring fair value. (The IFRIC3 interpretation issued by the International Accounting Standards Board (IASB) (2004) states that carbon emission rights should be defined as assets without physical form and should therefore be treated as intangible assets. However, intangible assets refer to identifiable non-monetary intangible assets owned or controlled by businesses.The concept of carbon emission rights is raised from the perspective of the natural environment, rather than business enterprises, so it is debatable to treat these rights as intangible assets (Peng *et al.* 2017).

The third view is to classify carbon emission rights as financial assets. US property law treats carbon rights as financial derivatives and allows them to be deposited in banks like securities. FRS13 published by the Accounting Standard Board (1998) proposes that carbon swaps be considered as financial derivatives.

2.2. Transaction Costs and CO_2 Emissions: An Empirically Tested Relationship

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. The empirical literature on transaction costs tests hypotheses and therefore refutes the claim that transaction cost economics is tautological. Most empirical studies are of the comparative static 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 transaction cost economics is fruitful. A complete overview would be beyond the scope of this essay.

2.2.1. 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 (*e.g.*, 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 (Jaraitë-Kaþukauskë and Kaþukauskas, 2014), 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

(Schleich and Betz, 2004; Jaraite *et al.*, 2010; Joas and Flachsland, 2014; Kerr and Dusch, 2015; Mundaca *et al*, 2013 and Ofei-Mensah and Bennett, 2013).

Coria and Jaraite (2018) 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 (CO2) 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.* (2020) 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. important. Second, they embed fixed and proportional trading costs in a standard permit market model.

Xiao *et al.* (2019) select 30 provinces (municipalities and autonomous regions) in mainland China as research subjects. As input they select coal, oil, natural gas, capital and labour. As output they consider GDP and carbon dioxide emissions in each province. They derive a distance function of carbon dioxide emissions with the Malmquist index model. They make an estimate on the environmental costs resulting from the uncontrolled pursuit of economic growth and the economic costs to reduce emissions during economic production by referring to the two-step BCC model which was used to analyze the shadow price and the costs. reduction in CO_2 emissions in each province. The main results obtained are as follows: There are clear differences in the efficiency of carbon emissions between provinces; The shadow price of carbon emissions works in a strong pattern; The effect of carbon reduction policy is attributed to regional interaction.

2.2.2 *Work on the Clean Development Mechanism (CDM)*

Michaelowaa and Jotzob (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 the study on Tanzania where it participates in the United Nations (UN) Climate Change Mitigation Strategy, which aims to reduce greenhouse gases (GHGs). This strategy 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 *et al*. (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. 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 2.1) 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 2.1 showing the correlation between CO_2 emissions and global transaction costs in a sample of 35 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.

4. METHODOLOGICAL APPROACH

Here it will be a question of presenting the different models used in the analysis and presenting the econometric technique used in the study.

4.1. Nature and Source of Data

The data used in this study are from secondary sources. Data on transaction costs come from the *Doing Business report*, 2019. Data on CO_2 emissions per capita,

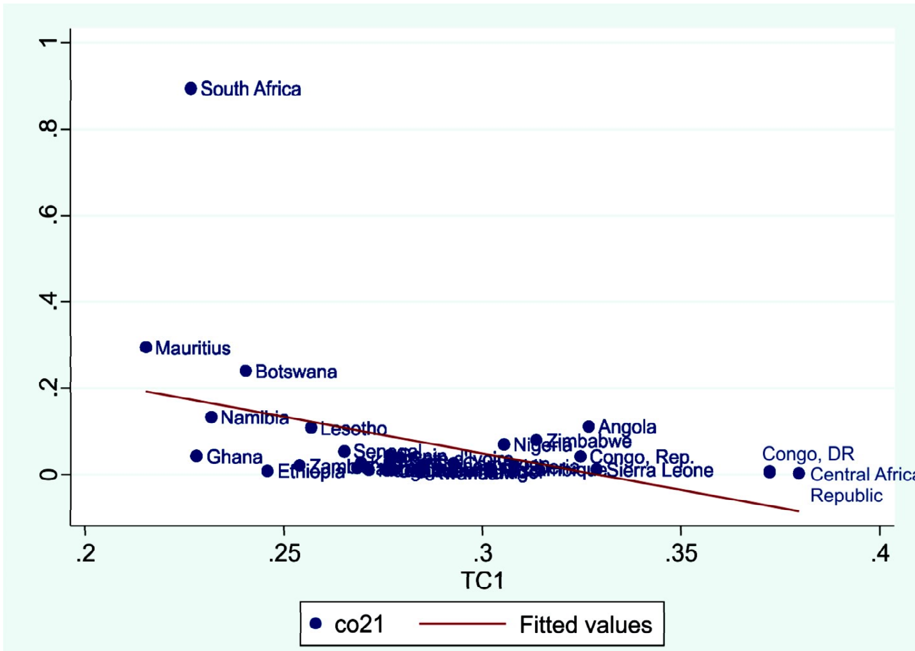

Chart 1 : Correlation between CO_2 emissions and global transaction costs

Source: Authors using Stata 14 software

urbanization, energy intensity, agriculture and industry come *from the World Development Indicators*, 2019. Data on PPP-adjusted real GDP per capita in constant 2005 prices are from *the Economic Research Service*. Regarding the temporal aspect, our research work covers the period 2003-2018 and concerns 33 countries in Sub-Saharan Africa.

4.2. Specification of an Econometric Model in the Relationship Transaction Costs and CO_2 Emissions

This is the presentation of the theoretical model on which the study is based and the empirical model on which it is based. The empirical specification is derived from a STIRPAT model, which is a stochastic form of the IPAT model. The IPAT model was developed theoretically by Ehrlich and Holdren (1971) and formalized mathematically by Commoner, Corr and Stamler (1971). It describes the effects of human activities on the environment. Although the IPAT model is a very useful theoretical framework, it does not allow testing of assumptions and is inflexible in the sense of proportionality restrictions between variables. To fill this gap, Dietz and Rosa (1997) developed a stochastic version of the IPAT model called STIRPAT.

This model allows us to see the stochastic effect of population, wealth and technology on the environment (York, Rosa and Dietz 2003).

In this document, the following empirical specification is adopted:

$$\ln CO_{2it} = \alpha + \beta \ln TC_{it} + \delta \ln CO_{2it-1} + \gamma \ln Z_{it} + \varepsilon_{it...} \quad (1)$$

Where, *i* is the individual dimension (country); *t*, the time dimension (year), α, β, δ *et* γ are model parameters, β captures the contribution of the decrease and/or increase in transaction costs on the quality of the environment, CO_{2it}, represents CO_2 emissions; TC_{it} a vector of variables of interest, in particular the variables on transaction costs, Z_{it} is a vector of control variables, CO_{2it-1} is the inclusion of the autoregressive term is 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 (namely the existence of an environmental Kuznets curve-EKC), the model used is specified by adding GDP per capita squared. However, a type of nonlinear effects are modeled. This model is used to analyze the robustness of the results, and it is specified as follows:

$$\ln CO_{2it} = \alpha + \beta \ln TC_{it} + \delta \ln CO_{2it-1} + \gamma \ln Z_{it} + \partial Gdp^2 + \varepsilon_{it...} \quad (2)$$

The variables to be explained here are represented by $CO_{2\ \text{emissions}}$ and are expressed in metric tons per head. Their measurements should not pose any particular problem since the observations are available in the World Bank database.

The independent variables or explanatory variables are subdivided into two: the variables of interest and the control variables. These are the main variables whose effects the study wants to estimate. They allow us to answer the main questions that we asked ourselves. They relate to transaction costs.

- ***Overall transaction costs***

Global transaction costs (denoted *TC*), represents the aggregate measure of transaction costs (expressed in dollars). The attempt to measure these transaction costs is based on the institutional dimensions of the costs incurred when firms participate in the market. Specifically, these are transaction costs induced by the underlying structure of the formal institutional framework, regulatory barriers and contract enforcement for economic exchange and market participation. The focus is more specifically on the transaction costs of institutional enforcement captured by the extent of formal institutional regulations, as advocated by De Soto (2003). Heindl (2015) finds that the costs of monitoring, reporting and verification (''MRV'') of emissions are positively related to $CO_{2\ \text{emissions}}$. Gold Coria and Jaraite (2019) come to the conclusion that there is a negative relationship between them. The literature not being unanimous, it is difficult to predict the sign.

• *Start-up costs*

Noted in the *BUS_C study*, this variable represents business-related costs. It measures the formal procedures required as well as the time and costs incurred by the entrepreneur to formally operate their business enterprise (expressed as a percentages of income per capita). Ease of starting a business captures the institutional barriers and costs associated with starting a business and participating in the market (Djankov *et al.* 2002).

• *Building permit costs*

Noted here *CONS_C*, this variable expresses the costs associated with obtaining building permits (expressed as a percentages of per capita income). It thus measures the official procedures, the number of days and the cost of building a warehouse in the construction sector.

• *Cost of property registration*

Property registration cost, (Noted in the study *PROP_C)* measures the sequence of formal procedures that a business must follow to purchase property from another business and to transfer title to the buyer's name in order to use it. This indicator therefore takes into account the cost and number of days required to complete the property registration procedure.

• *Tax payment costs*

The ease and administrative burden of paying taxes (*Denoted TAX_C)* and is expressed as a percentage of commercial profit, measures the difficulty of paying taxes and mandatory contributions for companies. This indicator considers the number of hours per year needed at the company level to prepare and pay corporate tax, value added tax and labor tax, as well as the total tax rate as a percentage of trading profit (Djankov *et al.* 2010).

• *Transaction costs related to the execution of contracts*

The ease of enforcing contracts (Noted *ENF_C)* measures the effectiveness of the judicial system in resolving a commercial dispute (expressed as a percentage of the value of the claim). The efficiency of the courts is broken down into three indicators:

(i) the number of procedures to enforce the contract, including filing and service of documents, trial and judgment and its enforcement;

(ii) the number of days required to complete the procedures; and

(iii) the cost necessary to complete the procedures.

The time required to complete the procedures is counted from the moment the plaintiff decides to take legal action until the final payment. The cost to complete the procedures excludes bribes and is measured as a percentage of the claim. It consists of court costs, enforcement costs and attorney fees. The ease of enforcing contracts captures the potential inefficiency of the judicial system in enforcing contracts (Djankov *et al.* 2003).

- ***Costs of insolvency proceedings***

The insolvency resolution indicator captures the time, cost and outcome of insolvency proceedings. It is noted in the *INS_C study and expressed as a* % of the debtor's mass . It is derived from responses to questionnaires from local practitioners of insolvency proceedings and bankruptcy systems. It takes into account the time required for creditors to recover the credit, expressed in number of calendar years, and the cost of proceedings, expressed as a percentage of the value of the debtor's estate. The total cost of insolvency proceedings includes court costs, insolvency administrator's fees, legal fees, appraiser's fees, auctioneer's fees and other related costs. The insolvency indicator includes the recovery rate from creditors. This recovery rate is measured as a percentage per dollar recovered by creditors, through company turnaround, liquidation or debt enforcement proceeds and indicates the present value of the debt recovered. The recovery rate is calculated after the official costs of insolvency proceedings and foreclosures are deducted, including the depreciation of equipment. Heindl (2015) finds that the costs of monitoring, reporting and verification (''MRV'') of emissions are positively related to CO_2 emissions. Gold Coria and Jaraite (2019) come to the conclusion that there is a negative relationship between them. The literature not being unanimous, it is difficult to predict the sign.

- ***Cross-border trade costs***

The cost of international trade (Noted *TRAD_C)* includes the cost of access to international markets. It thus measures the time and cost associated with exporting and importing a standardized container of goods by sea transport. This indicator takes into account the number of official import and export procedures as well as the time required to complete the procedures and the overall cost per standardized container of goods (Djankov *et al.* 2008). Trade opening would be favorable to pollution in Africa. This relationship, which validates the pollution haven hypothesis, highlights the negative environmental effects of liberalization policies in SSA. Because of the poor quality of their institutions, African countries would suffer ecological dumping, that is to say they would be attractive vis-à-vis polluting products. This relationship, systematized by Cole (2004) and Taylor (2005), has been discussed by many recent works (Solarin *et al.* 2017; Sapkota and Bastola 2017).

The control variables represent the effect of the structure of the economy on the environment estimated by GHG emissions. It's about :

- ***Urbanization (Ratio of urban population to total population, % total)***

Among the variables impacting carbon emissions, it is used in the study to represent the total population residing in urban areas. The study by Dogan and Tukerel (2016), Wang *et al* . (2019), Behera and Dash (2017) and that of Kasman and Duman (2015) reveal a positive effect of urbanization on CO_2 emissions. Al-Mulali and Ozturk (2015) conclude that urbanization increases environmental degradation. However, those of Charfeddine and Khediri (2016), Hossain (2011) and Sharma (2011) reveal a negative effect. The literature is not unanimous on the effect of urbanization on GHG emissions. Therefore it is difficult to predict the sign.

- ***Real GDP per capita (real GDP per capita adjusted for PPPs per capita in constant 2005 prices)***

According to Grossman and Krueger (1995), the literature has largely emphasized the role of a country's level of development on its polluting emissions. This result was validated by Friedl and Getzner (2003) and Andersson and Karpestam (2013). It is used to represent the level of change in economic growth in Sub-Saharan Africa and is approximated by real GDP per capita at constant 2005 purchasing power parity. Zhang and Zhang (2018), Shahbaz *et al*. (2013) and Chen and Lei (2018) show from their studies that economic growth positively influences CO_2 emissions. A positive sign is expected.

- ***Energy intensity (MJ/GDP in USD, PPP 2011)***

Regarding energy, the work of Dogan and Seker (2016), Apergis and Payne (2020), among others, is quite revealing of the strength of the relationship between this variable and CO_2 emissions. The main mechanisms are through energy demand, use of transport infrastructure, aggressive exploitation of natural resources and high deforestation (Sadorsky 2014; Salman *et al.* 2019).

- ***Agriculture (Agricultural value added (% of GDP))***

The dynamics of value addition in the agricultural and industrial sectors appear to be controlling pollution in Africa. Africa is the region of the world where the agricultural sector is dominant. Thus, the result remains consistent in an environment where agriculture remains very weakly mechanized.

- ***Industry (Industrial value added (% of GDP)***

Moreover, the effect of industrialization is paradoxical. It is negative for small polluters and positive for large polluters, the overall effect being negative. This also reflects the fact that industrial activity is more polluting in pollution-intensive countries. In the end, the industrialization of SSA would be weak. This partially validates the conclusion of Xu and Lin (2016), but contradicts those of Shahbaz *et al.* (2016) and Liu and Bae (2018). Ultimately, the observed positive relationship validates the predictions of environmental transition theory and ecological modernization theory when countries are in the early stages of development (Sadorsky 2014; Ohlan 2015).

4.3. Econometric Analysis 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 *et al.* (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 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).

MMG 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 MMG in differences and the estimator of Blundell and Bond (1998) or MMG in system. For the GMM in differences, the strategy to avoid endogeneity biases is to differentiate the level equations in first differences. Although this provides more accurate estimates than OLS, the use of level-lagged variables as instruments is not always appropriate and does not identify the effect of time-invariant factors. Moreover, Blundell and Bond (1998) show using Monte Carlo simulations that the GMM estimator in system is more efficient than that in first differences. Indeed, the latter gives biased coefficients on small samples when the instruments are weak. The bias is all the greater when the variables are persistent over time, when the specific effects are significant and when the temporal dimension of the panel is small. This is the reason why Arellano and Bover (1995) and Blundell and Bond (1998) complete the GMM estimation strategy on the difference equation with a GMM on the reference equation taken at level with variables delayed explanatory texts taken in difference as instruments. For the difference equations, additional moment conditions are used assuming that the explanatory variables are stationary, i.e. there is no correlation between the country-specific effect and the explanatory variables taken as a difference. The combination of equations in difference with those in level estimated simultaneously significantly increases the precision of the estimators when the explanatory variables are sufficiently auto-correlated (Blundell & Bond, 1998).

The technical conditions of use of MMGs have recently been elaborated by Roodman (2009a, 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 . 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 (equation 2.10) also allows the use of MMG. In view of the foregoing, the system generalized method of moments is used as an econometric estimation technique.

5. RESULTS AND DISCUSSIONS

5.1. Preliminary Results

5.1.1. Descriptive statistics

The descriptive statistics thus presented 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 0.01627 and its maximum value at 1. Its average value is positive at 0.16022. 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 into law a law imposing a tax on carbon emissions on companies in his country.

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 0.02344 and maximum value is 1)). Their means are all positive and respectively 0.2858; 0.0214; 0.0911; 0.3424; 0.13046; 0.3253; 0.3078; 0.2927; 0.2668. 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

Table 1: Descriptive Statistics

Variable	*Obs*	*Average*	*Standard. Dev.*	*Minimum*	*Max*	*Source*
CO_2 _	528	0.0726988	0.16022	–4.20E-09	1	World Bank (2020)
CT	528	0.285892	0.0551388	0.156	0.458	Doing Business (2020)
BUS_C	528	0.0214053	0.0539206	0	1	Doing Business (2020)
CONS_C	528	0.0911553	0.1377647	0.001	1	Doing Business (2020)
PROP_C	528	0.3424356	0.1943305	0.003	1	Doing Business (2020)
TAX_C	528	0.1304602	0.1466848	0.018	1	Doing Business (2020)
TRADE_C	528	0.2668247	0.1747239	0.0234498	1	Doing Business (2020)
ENF_C	528	0.3253674	0.2450615	0.046	1	Doing Business (2020)
INS_C	528	0.3078807	0.2031676	0.08	1	Doing Business (2020)
Urbanization	528	0.0884239	0.1383687	0	1	World Bank (2020)
GDP	528	0.1688138	0.2541727	0.0000136	1	World Bank (2020)
Agriculture	528	0.2965009	0.1988928	2.60E-09	1	World Bank (2020)
Energy_Int	528	0.2382652	0.1840877	0	1	World Bank (2020)
Industry	528	0.2784133	0.1630284	5.91E-09	1	World Bank (2020)

Source: Authors' construction

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.

5.1.2. Correlation Matrix

It is a question here of presenting the results of the correlation matrix which show 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.

5.2. Main Analysis Results

The estimation by the MMG-S 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 e" 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 Â0.10 for all estimates) and second order of Arellano and Bond (p-value e" 0.10 for all estimates) do not allow respectively to reject the hypotheses 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

Table 2: Correlation matrix

	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	1.0000													
CT	–0.3048	1.0000												
BUS_C	–0.1087	0.3873	1.0000											
CONS_C	–0.1870	0.4268	0.3111	1.0000										
PROP_C	–0.0885	0.3491	0.1966	0.2190	1.0000									
TAX_C	–0.1608	0.5672	0.4210	0.1661	0.1545	1.0000								
TRADE_C	–0.1406	0.3418	0.0356	0.4167	0.0910	0.0898	1.0000							
ENF_C	–0.2494	0.4412	0.2128	0.0859	0.0376	0.5097	0.1550	1.0000						
INS_C	–0.1872	0.4579	0.1451	0.2807	0.0912	0.3085	0.5304	0.2531	1.0000					
Urbanization	0.2519	0.0263	–0.0282	–0.1053	0.0448	0.0462	–0.1448	–0.1016	–0.0767	1.0000				
GDP	0.7745	–0.3647	–0.1413	–0.2687	–0.1094	–0.1874	–0.1376	–0.3152	–0.2266	0.0794	1.0000			
Agriculture	–0.4716	0.3079	0.1634	0.2312	0.0614	0.2306	0.1929	0.3081	0.5040	–0.0769	–0.5682	1.0000		
Energy_Int	–0.0838	0.1663	0.2184	0.1969	–0.0328	0.2167	–0.1256	0.2475	–0.0111	0.1145	–0.3172	0.2321	1.0000	
Industry	0.1278	0.0816	0.0223	0.0488	0.1301	0.0359	0.0243	–0.1418	–0.2075	0.0795	0.2005	–0.6453	–0.1911	1.0000

Source: Authors' construction

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, CO_2	0.339*** (0.00924)	0.608*** (0.00632)	0.640*** (0.00311)	1,391*** (0.0911)	0.649*** (0.0216)	0.442*** (0.00513)	0.515*** (0.00635)	0.475*** (0.0262)
CT	–0.106*** (0.00529)							
BUS_C		–0.00477** (0.00206)						
CONS_C			–0.00564*** (0.00165)					
PROP_C				–0.0117** (0.00567)				
TAX_C					–0.00414* (0.00234)			
TRADE_C						0.0132*** (0.00291)		
ENF_C							–0.0170*** (0.00311)	
INS_C								–0.0995*** (0.0352)
Urbanization	0.0338*** (0.00718)	0.0343*** (0.0108)	0.0314*** (0.00189)	–0.0195 (0.0248)	–0.00885 (0.0225)	0.0578*** (0.00777)	0.0466*** (0.00808)	0.00214 (0.0313)

	MMG in system							
Variables	*Dependent variable: CO_2 emission*							
Equations	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
GDP	0.203***	0.177***	0.170***	–0.174***	0.170***	0.244***	0.201***	0.261***
	(0.00376)	(0.00400)	(0.00185)	(0.0510)	(0.0136)	(0.00459)	(0.00552)	(0.0206)
Agriculture	–0.222***	0.00436	–0.0296***	0.0278*	–0.0164*	0.0214***	0.0126**	–0.0234
	(0.0285)	(0.00689)	(0.00243)	(0.0158)	(0.00868)	(0.00734)	(0.00479)	(0.0173)
Energy_Intensity	0.0263	–0.0117**	0.00293	0.00613	–0.0107**	–0.0299***	–0.0298***	–0.0295***
	(0.0173)	(0.00456)	(0.00253)	(0.0109)	(0.00490)	(0.00342)	(0.00443)	(0.00680)
Industry	–0.0755***	–0.0408***	–0.0279***	0.0759***	–0.0503***	–0.0569***	–0.0608***	–0.0808***
	(0.0120)	(0.00784)	(0.00399)	(0.0228)	(0.00787)	(0.00405)	(0.00635)	(0.0144)
Constant	0.122***	0.00541**	0.0110***	–0.0215**	0.0197***	0.00539***	0.0218***	0.0601***
	(0.00643)	(0.00433)	(0.00240)	(0.00940)	(0.00616)	(0.00196)	(0.00268)	(0.0183)
AR(1)	0.0708	0.0529	0.0520	0.0371	0.0418	0.0533	0.0527	0.0572
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

Standard errors in parentheses. (***$p < 0.01$, **$p < 0.05$, *$p < 0.1$).

Source: Authors' construction

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* demonstrate the positive impact of administrative *import restrictions* on CO_2 emissions. The positive and significant effect at 1%, the costs of cross-border exchanges would be favorable to pollution in Sub-Saharan Africa. This relationship, which validates the pollution haven hypothesis, highlights the negative environmental effects of liberalization policies in Africa. Because of the poor quality of their institutions, African countries would suffer ecological dumping, that is to say they would be attractive vis-à-vis polluting products. This relationship, systematized by Cole (2004) and Taylor (2005), has been discussed by many recent works (Solarin *et al.* 2017; Sapkota and Bastola 2017).

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 (2021). 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 would also be sensitive to energy intensity and is a significant factor in increasing pollution. According to the work Concerning energy, Dogan and Seker (2016) and Apergis and Payne (2020), are quite revealing of the strength of the relationship between this variable and CO2 emissions. The main mechanisms are through energy demand, use of transport infrastructure, aggressive exploitation of natural resources and high deforestation (Sadorsky 2014; Salman *et al.* 2019).

The dynamics of value addition in the agricultural and industrial sectors seem to control pollution in Sub-Saharan Africa. Both negative and significant at 1% , the results are in agreement with those of Mignamissi and Djeufack (2021). SSA is the region of the world where the agricultural sector is dominant. Thus, the result remains consistent in an environment where agriculture remains very weakly mechanized.

Moreover, the effect of industrialization is negative and significant at 1%. This also reflects the fact that industrial activity is more polluting in pollution-intensive countries. In the end, the industrialization of Sub-Saharan Africa would be weak. This validates the conclusion of Xu and Lin (2016), but contradicts those of Shahbaz *et al.* (2016) and Liu and Bae (2018).

5.3. Robustness of Results

To validate the consistency of the results, two robustness tests are carried out. The first verifies the existence of threshold effects of development on pollution by taking into account the quadratic form of this variable (GDP^2). The second test assesses the strength of the relationship with greenhouse gas emissions in order to understand the effects of transaction costs on overall pollution in Sub-Saharan Africa.

5.3.1. Threshold effects

According to Grossman and Krueger (1995), the relationship between development and pollution is not always monotonous. This non-linearity reflects the fact that not all levels of development are uniformly associated with all levels of pollution. Beyond a certain threshold, economic development would make it possible to control the level of polluting emissions. To do this, the model is re-estimated by integrating the quadratic variable of GDP per capita.

The results are presented in Table 4, and the existence of an environmental Kuznets curve (EKC) is observed. This means that the positive relationship between economic development and pollution changes beyond a certain threshold. In the early stages of development, economic activity tends to be more polluting due to the very high demand for environmental capital and the intense use of energy sources. However, as the country develops, environmental protection measures are adopted based on sustainability policies, which bends the pollution curve. According to Grossman and Krueger (1995), this result,

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.CO_2	0.532***	0.782***	0.736***	0.892***	1.006***	0.502***	0.619***	0.892***
	(0.00557)	(0.0127)	(0.00332)	(0.00540)	(0.00648)	(0.00518)	(0.00321)	(0.0108)
CT	–0.0575***							
	(0.00206)							
BUS_C		–0.00970***						
		(0.00118)						
CONS_C			–0.00749***					
			(0.00119)					
PROP_C				–0.00738**				
				(0.00335)				
TAX_C					–0.00433**			
					(0.00162)			
TRADE_C						0.00750***		
						(0.00183)		
ENF_C							–0.0319***	
							(0.00315)	
INS_C								–0.0727***
								(0.0216)
Urbanization	0.0549***	0.0280***	0.0311***	0.0200***	–0.0132***	0.0837***	0.0422***	–0.0117***
	(0.00678)	(0.00792)	(0.000745)	(0.00706)	(0.00231)	(0.00500)	(0.00591)	(0.00285)

MMG in system								
Variables	*Dependent variable: CO_2 emission*							
Equations	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
GDP	0.244***	0.171***	0.0336***	0.130***	0.0551***	0.0415***	0.131***	0.185***
	(0.00991)	(0.0160)	(0.00338)	(0.0152)	(0.00739)	(0.00962)	(0.00477)	(0.0161)
GDP^2	–0.0190***	–0.0478***	–0.115**	–0.0659***	–0.0675**	–0.300***	–0.0574*	–0.153***
	(0.00530)	(0.00663)	(0.00503)	(0.0107)	(0.00715)	(0.00777)	(0.00296)	(0.0114)
Agriculture	–0.00298***	0.0281***	–0.0309***	0.00822	–0.000601	0.0185**	0.0305***	–0.0293***
	(0.00643)	(0.00829)	(0.00154)	(0.00961)	(0.00635)	(0.00733)	(0.00705)	(0.00835)
Energy_Int	0.0124**	0.00261	0.00538**	–0.0123***	0.0141***	–0.0252***	–0.0104***	–0.0119***
	(0.00561)	(0.00397)	(0.00234)	(0.00447)	(0.00297)	(0.00369)	(0.00362)	(0.00343)
Industry	–0.0808***	–0.0332***	–0.0226***	–0.0514***	0.0116***	–0.0342***	–0.0524***	–0.0454***
	(0.00476)	(0.0102)	(0.00149)	(0.00874)	(0.00321)	(0.00410)	(0.00344)	(0.00538)
Constant	0.0278***	–0.00960***	0.0155***	0.00821**	–0.00682**	0.0144***	0.0137***	0.0390***
	(0.00351)	(0.00276)	(0.00111)	(0.00489)	(0.00252)	(0.00441)	(0.00311)	(0.00856)
AR(1)	0.0592	0.0499	0.0550	0.0495	0.0475	0.0665	0.0546	0.0493
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

Standard errors in parentheses. (***$p < 0.01$, **$p < 0.05$, *$p < 0.1$).

Source: Authors' construction

widely documented in the literature, should not be generalized. This phenomenon is particularly observed in resource-poor countries (Stern 2004). In these countries, the relationship between income level and pollution is U-shaped and not an inverted U.

5.3.2. The effect of transaction costs on global pollution[1]

It is essential to assess the effect of transaction costs on global pollution, one of the consequences of which is global warming. To do this, the nature of the link between transaction costs and greenhouse gas emissions is tested.

The results in Table 5 reveal that the transaction costs are factors of global warming, the effect remains negative and highly significant for the entire sample of SSA countries. This reflects the fact that transaction costs have an impact on global warming.

6. 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, in particular, property rights which are at the heart of the relationship between transaction costs and the environment; externalities as an environmental problem of transaction costs and emission permit markets as a means of internalizing environmental externalities. In terms of the empirical review, 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 test, which is to determine the effect of transaction costs on GHG emissions, in particular CO_2 emissions, the Generalized System Moments method 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 validate the consistency of the results, two robustness tests are carried out. The first verifies the existence of threshold effects of development on pollution by taking into account the quadratic form of this variable (GDP^2). The second test assesses the strength of the relationship with greenhouse gas emissions in order to understand the effects of transaction costs on overall pollution in Sub-Saharan Africa.

Table 5: Transaction costs and Greenhouse gases (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, GHGTc	1,002*** (0.00233)	0.964*** (0.0108)	0.994*** (0.00212)	0.994*** (0.00534)	0.999*** (0.00356)	1,009*** (0.00110)	0.995*** (0.00201)	0.997*** (0.00209)
CT	–0.0411*** (0.00502)							
BUS_C		–0.0891** (0.0122)						
CONS_C			–0.0397*** (0.00452)					
PROP_C				–0.00693*** (0.00206)				
TAX_C					–0.00604*** (0.00173)			
TRADE_C						0.00752*** (0.00128)		
ENF_C							–0.00274* (0.00140)	
INS_C								–0.0215** (0.00920)
Urbanization	0.00921*** (0.00171)	0.0124 (0.0106)	0.00752*** (0.00172)	0.00129 (0.00621)	0.00352 (0.00359)	0.00558*** (0.000635)	0.0102*** (0.00126)	0.00914*** (0.00162)

	MMG in system							
Variables	*Dependent variable: CO_2 emission*							
Equations	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
GDP	–0.00491**	–0.0191***	–0.0131***	–0.00515*	–0.0158***	–0.00211**	–0.00476***	–0.00302**
	(0.00254)	(0.00532)	(0.000998)	(0.00291)	(0.00338)	(0.000992)	(0.00134)	(0.00131)
Agriculture	–0.00576*	0.00122	0.0286***	–0.00237	0.0247***	0.0191***	0.00182	–0.00232
	(0.00591)	(0.0136)	(0.00393)	(0.00587)	(0.00837)	(0.00328)	(0.00261)	(0.00193)
Energy_Int	0.00276**	0.0555***	0.0195***	0.0311***	0.0163***	0.00172	0.00811***	0.00168
	(0.00312)	(0.00462)	(0.00177)	(0.00510)	(0.00460)	(0.00137)	(0.00121)	(0.00165)
Industry	–0.00388*	–0.0467***	–0.0299***	–0.0356***	0.0346***	–0.0101***	0.0113**	0.00638*
	(0.00227)	(0.0117)	(0.00467)	(0.00677)	(0.00754)	(0.000847)	(0.00178)	(0.00134)
Constant	0.0119***	–0.0241***	–0.0187***	–0.0121***	–0.0207***	–0.0100***	–0.00395***	0.00576**
	(0.00324)	(0.00701)	(0.00221)	(0.00346)	(0.00428)	(0.000737)	(0.00141)	(0.00306)
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

Standard errors in parentheses. (***$p < 0.01$, **$p < 0.05$, *$p < 0.1$).

Source: Authors' construction

In accordance with the results, it is recommended that the authorities set up and ensure the application of property rights and emission permit markets which present themselves as a solution to the problem of environmental externalities posed.

Note

1. Greenhouse gases (GHGs) are gaseous components that absorb infrared radiation emitted by the Earth's surface and thus contribute to the greenhouse effect. The increase in their concentration in the Earth's atmosphere is one of the factors of global warming. The main GHGs naturally present in the atmosphere are water vapour, carbon dioxide, methane, nitrous oxide and ozone.

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