Evaluation of the effects of institutional failure on the eco-efficiency of charcoal producers in the Congo basin: the case of Cameroon

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Abstract: **The objective of this paper is to assess the effects of institutional failure on the level of eco-efficiency of charcoal producers in Cameroon. The study covers 232 randomly selected producers in two socio-ecological zones in Cameroon. To analyse the data, we used a stochastic production technology and a quadratic regression model to assess the level of eco-efficiency and the effects of institutional failure on it, respectively. The result of these analyses is that bribes capturing institutional failure have negative effects (-0,0044877) on eco-efficiency indices, but when bribes exceed 49,533 FCFA, their effects become significantly positive (0 ,0000453) on eco-efficiency indices. Therefore, any policy aimed at improving sustainability in charcoal production in the region must take into account the levels of institutional constraints associated with each socio-ecological zone.**

Keywords**: Evaluation, Institutional failure, eco-efficiency, charcoal, Congo Basin, Cameroon**

I. INTRODUCTION

Charcoal is a common property resource. One of the major problems associated with the sustainable management of such a resource is the 'tragedy of the commons. This assumption by Hardin (1968) has become the underlying theoretical framework for analyzing models of natural resource allocation. The environmental economics literature identifies three institutional models: public ownership, private ownership and community ownership (Holland and Sene, 2010; Le Meur, 2010). However, each of these institutional models has a controversial theoretical basis.

Indeed, institutions are not acceptable in economics outside the market. According to the assumptions underlying general equilibrium theory, it is inconceivable to dictate rules in economics. The market is the only mode of coordination of individual behaviour (Mckenzie, 1981, Arrow and Debreu, 1954). This coordination takes place through price mechanisms, which ensure the general equilibrium of the economic system. This mode of coordination promoted by general equilibrium theory is based on Walras' 'auctioneer' [1]and the principle of the 'invisible hand[2]'. But for some disequilibrium theorists, such as Keynes (1936), Clower (1975), Leijonhuvud (1968), the general equilibrium model of the Arrow-Debreu universe seems more theoretical than practical. The economic system is fraught with uncertainty. Economic agents have bounded rationality (Ayres and Gertner, 1992; Simon, 1951). In addition, some economic activities, such as charcoal mining, generate greenhouse gases whose costs[3] are borne by the community. And these costs are not taken into account by market regulation mechanisms. Hence the "market failure" hypothesis (Meade, 1973).

In the context of market failure, public regulation seems to be the best mode of sustainable natural resource management (Arrow, 1985; Pigou, 1938). However, public intervention is seen as a political tool for interest groups that can undermine collective welfare (Shleifer and Vishny, 1993). Moreover, public regulation is sub-optimal in the Pareto sense of the 'Coase theorem' (Coase, 1992). Rather, it is a two-way problem[4]. Furthermore, Coase (1960) argues that sustainable management of natural resources can be achieved through price mechanisms, even in the presence of negative externalities[5]. To do this, property rights over the resource must be defined. Rights that can be exchanged on a

[1] Walras explains that a fictitious agent, the auctioneer, receives information on the quantities that the agents wish to exchange and sends them prices that inform them of the scarcity of a particular good

[2] A concept theorised by Adam Smith, which states that the pursuit of self-interest leads to an optimal allocation of resources.

[3] The exploitation of charcoal imposes a cost on communities without any payment being made: for example, the costs of pollution emitted during charcoal mining activities

[4] For Coase (1960), the resolution of environmental problems can only come from a bilateral negotiation between the sender and the victim, i.e. from a bargaining between the economic agents concerned. According to Faucheux and Noel (1995): "A inflicts damage on B. And one must decide how to restrict A's activities. But this is wrong. The economic agents are faced with a problem of a reciprocal nature. Avoiding harm to B will harm A. The real question is whether to allow A to harm B or B to harm A.

[5] We speak of externalities when a person "A at the same time as he provides a given service to person B for which he receives payment, provides at the same time advantages and disadvantages of such a nature that a payment cannot be imposed on those who benefit from it, nor a compensation for those who suffer from it" (Pigou, 1922).

competitive market system. Coase thus gives back to market mechanisms the attributes that were theirs in the general equilibrium model of the Arrow and Debreu universe (1954). Through these new attributes, the neoclassical channel once again becomes the theoretical framework par excellence for analysing and solving environmental problems (Cropper and Qates, 1992; Fisher and Peterson, 1971).

Given the nature of the good in question, the definition of a private property regime is not appropriate. Following the work of Ostrom (1990) on common property, researchers have proposed a third mode of governance, one that falls between market and state institutions, based on the self-organisation of user communities (Le Meur, 2010). Cameroon in particular and the Congo Basin, in general, have seen the emergence of this institutional model through the lens of community forests. Indeed, institutions themselves are quite multidimensional. Although they are the rules of the game of society or more formally the constraints that structure human interactions (North, 1990). A distinction is made between formal and informal institutions. As soon as the missions that have been assigned to these different institutions are not achieved or have been diverted to the benefit of the interest group, we speak of institutional failure.

Thus, institutional failure is a dysfunctional model of resource allocation (Newig et al, 2019; Acheson, 2006). It has been interpreted in different ways, depending on the disciplinary and methodological perspective adopted. The innovation approach, led by Woolthuis et *al*, (2005) subdivides institutional failure into two: 'hard institutional failure' focusing on the failure of regulations and the legal system and 'soft institutional failure' based on failures of social institutions such as political culture and social values. In the wood energy sector, this institutional failure is reflected in the corrupt[6] behaviour of administrative and communal officials (Sola et al., 2019) and parafiscality (Eba'a Atyi et al.2016; Madi, 2012).

In the 1990s, faced with the challenges of sustainability[7] in the forestry sector, the countries of the Congo Basin[8] embarked, with the support of the World Bank, on a process of reforming their legislative and institutional framework for the sustainable management of forest resources. In Cameroon, this reform resulted in the Forestry Law No: 14/01 of 20 January 1994. Two objectives were pursued by the World Bank (Carret, 2000): to increase state revenues and to promote sustainable management of forestry assets.

The 1995 decree on the modalities of implementation of this law regulates the exploitation of fuelwood at two levels. (i) the exploitation permit for certain special products, including charcoal, and (ii) the exploitation permit for firewood. To capture the revenue generated by the sub-sector, the government mobilises two instruments (Sola, 2019): (i) the regeneration tax, applied to special products, including charcoal, and (ii) the tax on the stere of wood, which is part of the general taxation of the sector. To these two instruments should be added the licences that the government grants to agents to collect the dead wood in North Cameroon. However, the results of this reform seem to be mixed (Kabaka, 2017). The contribution of the wood energy sub-sector to state revenues is marginal (Eba'a Atyi et al., 2016). Much of this revenue is captured by administrative and communal officials through corruption and parafiscality (Madi, 2012). In addition, the environmental sustainability objective of the sub-sector has not been achieved (Sola et al., 2019; Mulenga et al., 2015). This is because wood energy exploitation increases deforestation and soil erosion around two major cities in the North (Folefack and Abou, 2009). This soil erosion is at the origin of the decline in agricultural productivity in the areas concerned. Charcoal production results in net GHG emissions and deterioration of biodiversity and natural resources such as forests, water and soil (Dam, 2017).

The decade of reforms and efforts made in the forestry sector has resulted in a kind of unanimity within the scientific community. A large number of articles and reports have agreed over the past decade on the existence of a crisis in forest governance that is undermining the sustainability of the sector (Cebu et al,.2016; Lescuyer, 2013; Cerutti et al., 2013). However, in the wood-energy sub-sector, these papers do not assess the effects of institutional failure on the eco-efficiency of charcoal producers. Like fuelwood, charcoal is the main source of energy in developing countries in both rural and urban areas (Sola et al., 2019; Schure et al., 2014; Kendagor and Prevost, 2013). In addition, the greening of the charcoal value chain has considerable potential to reduce global greenhouse gases (Dam, 2017).

It should also be noted that eco-efficiency refers to the ability of a firm, industry or economy to produce goods and services with a less negative impact on the environment (Picazo-Tadeo et al., 2012). It is a compromise concept between the quest for economic efficiency and the environmental efficiency of production units. Empirical studies have indeed assessed the effects of institutional failure on the economic [9]and environmental[10] efficiency of production units through the channel of corruption. But these

[6] bribes, baksheesh, ...Etc.

[7] According to the United Nations Commission on the Environment, sustainability refers to "paths of human progress that meet the needs and aspirations of the present generation without compromising the ability of the future generation to meet theirs" (WCED, 1987). The debate on these issues was initiated in 1972 by the Meadows report The Limit of Growth, which predicted that our economic society would collapse in the first half of the 21st century if the causes of our future perdition, namely population growth, energy expansion and technological change, were not addressed (Meadows et al., 1972).

[8] The Congo Basin is the second largest forest area in the world after the Amazon. Six countries are part of the Congo Basin: Cameroon, CAR, Congo, DRC, Equatorial Guinea and Gabon

[9] Aidt, 2019; Aidt et al, 2008; Méndez and Sepúlveda, 2006; Hellman et al, 2003; Slinko et al, 2002; Mo, 2001; Davoodi, 2000; Tanzi and Davoodi, 2001; Mauro, 1995

[10] Welsch (2004), Wilson and Damania (2005), Fredriksson et al (2007), Fredricksson and Svensson (2003), Lopez and Mitra (2000)

empirical discussions are, to the best of our knowledge, approached from a macroeconomic perspective. At the micro-level, the existing empirical evidence does not question the effects of institutional failure on the eco-efficiency of charcoal producers in Cameroon. In light of these failures, the objective of this paper is to assess the effects of institutional failure on the eco-efficiency of charcoal producers in Cameroon. This assessment will identify the levels of institutional failure that contribute to the preservation of the environment and the levels of institutional failure that contribute to its deterioration. In the following sections, we will first present the methodological approach (2). Secondly, we will present the results (3). Finally, the conclusions with some recommendations will be made (4).

II. METHODOLOGICAL APPROACH AND DATA

2.1. Econometric model

The researchers proposed a two-stage econometric method. First, the eco-efficiency of charcoal operators was assessed. The literature distinguishes between two main approaches to eco-efficiency estimation: the mathematical programming approach (Galanopoulos et al., 2006; Lansink and Reinhard, 2004; Farrell, 1957) and the Stochastic Frontier Analysis (Coelli et al. (Coelli et al.,1998, Aigner et al., 1977). But given the empirical work (Adenuga et *al.*, 2019; Bonou-zin et *al.*, 2019; Duman and Kasman, 2018; Mamardashvili et al., 2016; Cuesta et al., 2009), the stochastic specification of the production technology in the form of a hyperbolic distance function has been mobilised in this work. Charcoal is a "desirable output" because it meets human energy needs. The CO2 generated by the charcoal production technology is an 'undesirable output'. Because they contribute to global warming (Temmerman et al., 2019). Following the framework outlined by Bonou-zin et al, (2019), Adenuga et al, (2019), Cuesta et al, (2009), the hyperbolic distance function (HDF) allows evaluating simultaneously forgiven producer I, the maximum amount of charcoal and the minimum amount of CO2 needed to stay on the frontier (F) of the production technology without the inputs changing.

According to the work of Cuesta, *et al*, *(*2009), the following charcoal production technology is used:

$$T(x,y,z) = \{(x,y,z): x\ peut\ produire\ (y,z); x \in \mathcal{R}^K, y \in \mathcal{R}M, z\in\mathcal{R}R \qquad (1)$$

A technology that uses a set of inputs $x = (x_1;\ x_2; \dots; x_k) \in \mathcal{R}^k$ to produce a set of desirable outputs (charcoal) $y = (y_1; y_1; \dots.; y_m) \in \mathcal{R}^M$ and a set of undesirable outputs (CO2) $z = (z_1; z_2 \dots.; z_r) \in \mathcal{R}^R$. And this production technology satisfies the production axioms demonstrated by Färe and Primont (1995). And it can be specified as a hyperbolic distance function (Bonou-zin et al., 2019). Doing so, we have the following formulation:

$$D_H(x,y,z) = inf\{\theta > 0: (x, \theta^{-1}y, \theta z) \in T\} \qquad (2)$$

Based on the flexibility of the Translog functional form, the homogeneity conditions and the restriction hypothesis to the substitution between inputs and outputs, Cuesta *et al.* (2009) developed a hyperbolic distance function of Translog type whose mathematical expression is as follows

$$lnD_H(x,y,z) = \alpha_o + \sum_{m=1}^{M} \alpha_m lny_m + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M} \alpha_{mn} lny_m lny_n + \sum_{k=1}^{K} \beta_k\ lnx_k + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{kl} lnx_k lny_l + \sum_{r=1}^{R} \gamma_r lnz_r +$$

12r=1Rs=1Rγrslnzrlnzs+m=1Mk=1Kδmklnymlnxk+ m=1Mr=1Rψmrlnymlnzr+k=1Kr=1Rμkrlnxklnzr

Let the empirical model specification be as follows:

$$-lny_i = \alpha_o + \sum_{K=1}^{4} \beta_k lnx_{ki} + \frac{1}{2}\sum_{k=1}^{4}\sum_{l=1}^{4} \beta_{kl} lnx_{ki} lnx_{li} + \delta_1 lnz_{ri} y_i + \delta_{11} lnz_i y_i lnz_i y_i + \sum_{k=1}^{4} \varphi_{kr} lnx_{ki}\ lnz_i y_i + v_i - \omega_i \qquad (3)$$

The empirical model shows that only one desirable output (charcoal), one undesirable output (CO2) and four production factors are taken into account in the estimation of eco-efficiency indices:

x_1: Cost of wood supply borne by producer i

x_2: Cost of processing wood into charcoal borne by producer i

x_3: Cost of spreading wood energy borne by the producer i

x_4: Labour employed by a farmer I in the production process

y_i: Charcoal produced by producer i

Z_i: CO2 emissions generated by the producer i

Following the empirical literature, we subsequently postulate a non-linear relationship between institutional failure and eco-efficiency. The existence of the non-linear relationship between economic variables is modelled through threshold models (Chen and Sun, 2018; Henderson et al., 2017; Hansen, 2000), the quadratic regression model (Rutayisire, 2015; Quartey, 2010; Pollin and Zhu, 2005; Clements et al., 2005). To our knowledge, the assumptions underlying threshold models generally require the use of time-series data. However, in this study, we are dealing with cross-sectional data. Hence the use of the quadratic regression model.

Consider the following general expression for a standard quadratic regression model with two variables of interest:

$$Q(x,y) = ax^2 + bxy + cy^2 + dx + ey + f \qquad (4)$$

Let $\Delta = b^2 - 4ac$ be its discriminant which is the opposite of the Hessian determinant. The discriminant is also called the realizer. It should be noted that in mathematics, the discriminant is used to solve equations of the second degree. If the discriminant is strictly positive, the function has a hyperbolic quadratic as its representative surface, if it is strictly negative, it has an elliptical paraboloid as its representative surface. In the case where the discriminant is equal to zero (the degenerate case), the function has a hyperbolic cylinder as its representative surface.

In mathematics, especially in Euclidean geometry, a hyperbolic cylinder is a degenerate quadratic: the rank of the quadratic form associated with a hyperbolic cylinder is 2. And its reduced equation is of the following form

$$\frac{X^2}{a^2} - \frac{Y^2}{b^2} = 1 \qquad (5)$$

Where a and b are the parameters of the hyperbola. A paraboloid is a surface of the second degree in Euclidean space. Some sections of a paraboloid are parabolas, others are ellipses or hyperbolas. For this reason, a distinction is made between elliptical and hyperbolic paraboloids. In a well-chosen reference frame, its equation is of the form:

$$(\frac{x}{a})^2 + (\frac{y}{b})^2 - z = 0.$$

It should be noted that, outside the degenerate cases, the quadratic function admits a single critical point, whose coordinates are the solutions of the system of equation (6):

$$\begin{cases} 2ax + by + d = 0 \\ bx + 2cy + e = 0 \end{cases} \qquad (7)$$

Based on the general formulation of the standard quadratic regression model, we can establish through a quadratic function a measure of the non-linear relationship between institutional failure and eco-efficiency of charcoal producers in Cameroon.

The econometric specification of the non-linear effects of institutional failure on eco-efficiency through the quadratic regression model is as follows:

$$IE_i = \beta_0 + \beta_1 potdvin_i + \beta_2 potdvin_i{}^2 + \alpha_i X_i + \varepsilon_i, \qquad (8)$$

With IE_i , representing the eco-efficiency indices of producer I; $potdvin_i$ indicates the number of bribes paid by a producer I in CFA francs. We find that, $potdvin_i$ would have a negative sign. To this end, they reflect the adverse effects of institutional failure on eco-efficiency indices. The variable bribes squared ($potdvin_i{}^2$) should have a positive sign and should measure the beneficial effect of bribes on eco-efficiency indices. Finally, X_i, let us look at other explanatory variables that enter the model. These are the socio-economic characteristics of the producer.

It should be noted that $potdvin_i{}^2$ increases in value faster than $potdvin_i$. This implies that the presence of positive effects of corruption will eventually outweigh the negative effects. Moreover, the combination of the significantly negative linear term ($potdvin_i$) with the significantly positive squared term ($potdvin_i{}^2$) suggests that the effect of institutional failure on the eco-efficiency of the sector can be described as an inverted U-shaped curve. This supports our view. A view that institutional failure has significantly negative effects on eco-efficiency, but when this failure exceeds a threshold effect level, its effects become positive on eco-efficiency indices. Hence the hypothesis of the 'crowding out effect' of corruption on charcoal producers.

The peak of the quadratic function identifies the institutional failure threshold or turning point above which the marginal effect of the bribe variable becomes positive on the eco-efficiency indices. To calculate the critical point corresponding to the institutional failure threshold, we calculate the partial derivative of equation (8):

$$\delta EE_i / \delta potdvin_i = \beta_1 + 2\beta_3 potdvin_i \qquad (9)$$

And by equalising to zero, we have:

$$\beta_1 + 2\beta_3 potdvin_i = 0 \qquad (10)$$

The solution of the model is materialised by the critical point or threshold. It is found by solving equation 10. In doing so, the threshold of the bribe variable (6) ($potdvin^*$), which is the number of bribes beyond which the marginal effect of bribes becomes negative on environmental performance.

2.2 Source of data

The data used in this study are both primary and secondary. The secondary data comes from the literature review and concerns estimates of CO2 emissions generated by charcoal production technology (Dam, 2017). These estimates were used to calculate the "unwanted output" used in this study. And the primary data was obtained through funding from the *Conservation Action Research Network* (CARN) of the *ASPIRE Research* program from which this work benefited. They were collected during individual interviews with woodfuel producers using a well-structured questionnaire. The producers selected were those who were involved in wood energy as an income-generating activity. A total of 645 questionnaires were administered through the snowball sampling technique, of which 518 were usable. However, after processing the data through data analysis tools, a database of 491 woodfuel producers was established. From this database, we extracted 232 charcoal producers, distributed as follows.

Table 1: Distribution of the sample

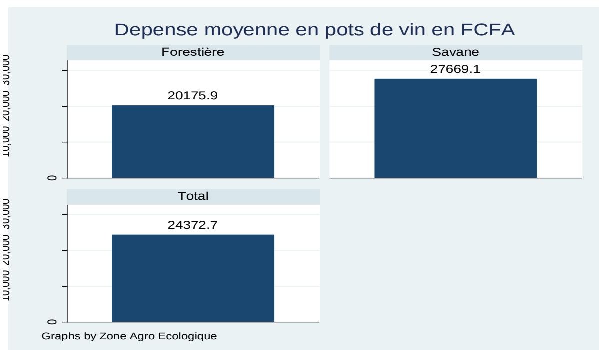
AGRO-ECOLOGICAL AREA	REGION	CHARCOAL PRODUCERS
FOREST AREA	East	39
	South	60
	TOTAL	99
SAVANNAH AREA	Far North	78
	North	55
	TOTAL	133

Author: 2021 based on survey data

In doing so, information was obtained on the level of corruption in the area. Graph 4 shows that, on a global scale, fuelwood operators spend an average of 24,372.7 XAF to bribe communal agents, water and forestry agents, road safety agents, etc. And in the socio-ecological zone, forestry operators spend an average of 20,175 XAF to bribe these agents. The amount is higher for farmers in the savannah zone, who spend an average of 27 669 XAF.

These different bribe expenses increase the transaction cost. Because these expenses are added to the production costs of charcoal. Given that economic performance is a decreasing function of transaction costs. The increase in the latter has deteriorated the economic performance of producers.

Graph 1: Average expenditure on bribes in XAF



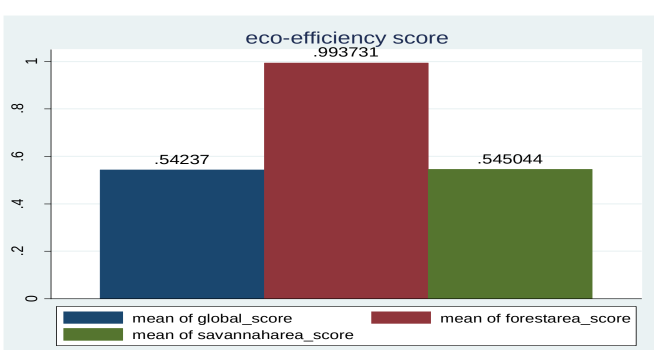
Source: Author 2021, based on survey data

III. RESULTS AND DISCUSSION

3.1. Eco-efficiency index of charcoal producers

After estimating the hyperbolic distance function, Figure 1 shows that the average eco-efficiency index at the global scale is 0.54237. That of the forest area is 0.9937, higher than that of the savannah, which is 0.545044. There are potentials in production technology to improve the eco-efficiency of farmers in both the forest and savannah zones, taking into account the global scale as well. To do so, charcoal farmers at a global scale could increase their production by 84.37% (1/0.54237) while reducing CO2 emissions by 45.76% (1-0.54237). In the forest area, coal producers can increase their production by 0.63% (1/0.9937) while reducing CO2 emissions by 0.63%. Coal producers in the savannah can increase their coal production by 83.47% (1/0545044) while reducing their CO2 emissions by 45.49% (1-0.545044).

Graphic 2: Eco-efficiency score



Source: Author 2021, based on survey data

3.2. The statistical description of the relationship between bribes and average eco-efficiency indices

To describe the relationship between bribes and eco-efficiency, we have linked in Table 2 the levels of bribes with eco-efficiency indices. At the aggregate level, when the amount of bribes paid by the farmer is less than 25,000 XAF, the average eco-efficiency index is 0.7005604. And at more than 25,000 XAF, i.e. between 25,000 and less than 50,000 XAF, the average eco-efficiency index is 0.70; 0.4778. Between 50,000 XAF and less than 75,000 in XAF of the number of bribes paid, the average eco-efficiency bounces back to 0.7088; to falls back to 0.1473, when the amount of bribes paid is between 75,000 XAF and less than 100, 0000 XAF. Thereafter, the eco-efficiency index rebounds to 0.5696 when the amount of bribes paid is greater than or equal to 100,000 XAF.

In the forest area, when the amount of bribes paid by the logger is less than 25.000 XAF, the average eco-efficiency index is 0.54418. And at more than 25,000 XAF, that is, between 25.000 and less than 50,000 XAF, the eco-efficiency index is 0.6794. Thus, a slight increase. These two modalities related to the number of bribes paid do not allow conclusions to be drawn a priori on the type of relationship between bribes and the average eco-efficiency score in the forest area.

In the savannah area, when the amount of bribes paid by the farmer is less than 25,000 XAF, the average eco-efficiency index is 0.5896. And at more than 25,000 in XAF, i.e. between 25,000 and less than 50,000 XAF, the eco-efficiency is 0.4778. Between 50,000 XAF and less than 75,000 XAF of the number of bribes paid, the average eco-efficiency index rebounds to; 0.7341 to fall back to 0.1473, when the amount of bribes is between 75,000 XAF and less than 100,000 XAF. After that, the average index rebounds to 0.5696 when the amount of bribes paid is greater than or equal to 100,000 XAF. We can deduce that there is a sawtooth evolution.

The main results that emerge from these descriptive statistics do not allow us to determine the type of the relationship between bribes and the eco-efficiency score" or the usefulness for us of making econometric estimates. These estimates will allow us to definitively identify the meaning of the relationship between bribes and the eco-efficiency score.

Table 2: Relationship between bribes and average eco-efficiency score

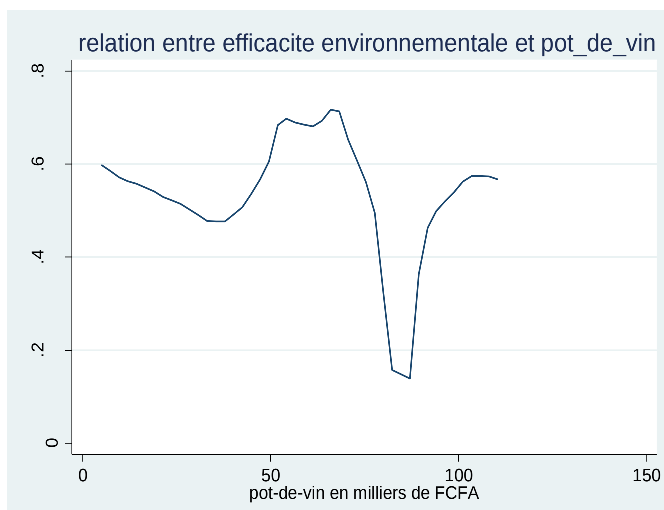
Bribes in XAF	average eco-efficiency index			
	Average eco-efficiency score on a global scale.			
	Observation	**Mean**	**Minimum**	**Maximum**
[5000-25000[	145	0.5604766	0 .0753395	0.9979798
[25000-50000[	65	0.4778973	0.0723827	0 .9963235
[50000-75000[	13	0 .7088746	0 .3864748	0 .9963483
[75000-100000[	2	0.1473021	0.1026457	0.1919585
[100000-120000[	7	0 .5696215	0 .387977	0.7406427
Bribes in XAF	**Average eco-efficiency index in the forest area.**			
	Observation	**Mean**	**Minimum**	**Maximum**
[5000-25000[	93	0.5441857	0 .0851903	0.9961309
[50000-75000[	6	0.6794201	0.3864748	0.9956742
Bribes in XAF	**Average eco-efficiency index in the savannah area.**			
	Observation	**Mean**	**Minimum**	**Maximum**
[5000-25000[	52	0.5896121	0.0753395	0.9979798
[25000-50000[	65	0.4778973	0.0723827	0.9963235
[50000-75000[	7	0.7341213	0.4757639	0.9963483
[75000-100000[	2	0.1473021	0.1026457	0.1919585
[100000-120000[	7	0.5696215	0.387977	0.7406427

Source: Author 2021, based on survey data

3.3. Non-linear effects of institutional failure on the eco-efficiency of charcoal farmers in Cameroon

To be sure of the functional form, the linearity test and the specification of the functional form were performed. It turned out that the bribe can be specified in quadratic form. The test showed that there is no linear relationship between eco-efficiency indices and the bribe variable. So, looking at Table 3, the results show that the effects of bribes on the eco-efficiency scores of woodfuel operators are significant. The estimation of the quadratic regression model revealed a significantly negative coefficient associated with bribes. This reflects the negative effects of bribery on eco-efficiency scores. And the significantly positive coefficient associated with bribes squared. Measuring the adverse effect associated with a high level of bribes on operators' eco-efficiency scores. Based on the significance of these different coefficients, we determined the peak of the quadratic function. Thus, the effect of bribes on operators' eco-efficiency scores can be described as a U-shaped curve as shown in Figure 3. As a result, there is a non-linear relationship between institutional failure and the external sustainability of the wood energy sector.

Figure 3: Relationship between environmental effectiveness and bribes



Source: Author 2021, based on the estimated model

After estimating the model. The partial derivative was calculated. Then, solving this partial derivative shows that, bribes have significantly negative effects on farmers' eco-efficiency scores, but when bribes exceed 49,533 XAF, their effects become significantly positive on farmers' eco-efficiency scores.

Table 3: Overall estimation of the quadratic regression model

Variables	**External sustainability of the sector**
	Eco-efficiency score
Bribes	-0,0044877* (-1.72)
Bribes squared	0 ,0000453* (1.81)
Opportunistic behavior index	0,0095652 (0.54)
Over 50 years	-0,3589828*** (-4.31)
Man	0 ,355519* (1.84)
Education	-0,2134862*** (-5.02)
Training	0 ,075042 (0.62)
Parallel work	-0,2800769* (-1.86)
Diversification	-0,3788324*** (-8.80)
Sanction	0,0595396* (1.80)
Distance traveled to collect wood	.0145096 (1.01)
Member of association	-0,2392877 (-1.39)
_cons	1.067251 *** (8.19)
Obs.	232
R-squared	0.4639

Source: Author 2021, constructed from estimation results, Significant at 1% *** p<0.01, at 5%** p<0.05, and at 10%* p<0.1

Indeed, the negative coefficient associated with bribes reflects the negative effects of bribes on environmental quality. This is because bribery negatively affects the adoption of environmental regulations and leads to overexploitation of natural resources. These same conclusions were drawn by Delacote (2005). In addition, the significantly positive coefficient of bribes squared shows that the higher the amount of bribes, the more beneficial its effects on the environment. This is since the increase in bribes generates exorbitant costs that negatively affect the operator's profit margins, causing successive losses. Operators, therefore, prefer to abandon the business. We postulate a 'crowding out effect of bribes in the sector. The abandonment of charcoal and fuelwood exploitation by some operators reduces their hold on natural resources. This contributes to the preservation of forest resources. There is talk of the indirect effects of bribes on environmental quality. The same conclusions were drawn by Cole (2017) at the macro level where corruption affects the quality of the environment through its harmful effects on economic growth.

In addition, certain control variables have established our attention with regard to their significance on the eco-efficiency scores of producers. We wanted to highlight them. These are age, gender, sanction, diversification and many more.

On reading the table, it is clear that producers over 50 have significantly negative eco-efficiency scores with regard to the sign of the coefficients. This implies that producers over 50 care less about preserving the environment than farmers under 50. This is explained by the fact that producers over the age of 50 have felt that they no longer have an interest in preserving natural resources. They prefer to maximize their present gain at the expense of future gain. Since they make the assumption that in the long term, they will no longer be alive. As a result, the principle of intergenerational equity which is the basis of the concept of sustainable development is set aside by producers over 50 years of age.

Regarding the gender variable, being male has significantly positive effects on eco-efficiency scores with respect to the sign of the coefficient. Thus, we can deduce that men care more about the environment than women in the wood-energy sector. In fact, the wood-energy exploitation activities required a great deal of physical effort. And sometimes you have to spend days and nights in the coal mining sites to watch the millstones. Because during the carbonization, it can happen that the wheels are destroyed. Which is a source of CO_2 emissions. Where women are divided between domestic work and the exploitation of charcoal. They spend less time looking after their millstones and cannot spend the night like men in the carbonization sites.

The application of sanctions is beneficial to the environment. It contributes to the preservation of forest resources. According to our estimates, we find that the sanction effect on the eco-efficiency scores of producers is significantly positive. Sanctions lead wood-energy operators to adopt the rules for the preservation of the environment enacted by the public authorities.

IV. CONCLUSION AND IMPLICATIONS

In this study, we aimed to assess the effects of institutional failure on the level of eco-efficiency of coal producers in Cameroon. In summary, the main findings are as follows: Producers have room for manoeuvre to improve their eco-efficiency level and the effects of institutional failure on eco-efficiency vary according to the level of failure.

Given these results, some recommendations can be made. Charcoal producers are advised to diversify their wood supply to reduce the level of CO_2 emissions from deforestation. But any policy aimed at improving eco-efficiency must take into account the level of institutional constraints related to each socio-ecological zone.

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