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Decomposition of the Environmental Kuznets curve for Deforestation in the Congo Basin

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Abstract

This study examines the theoretical relationship between economic growth and natural resource depletion. We decompose the determinants of the economic growth into three structural effects (scale, technique, and composition effects). This model is tested with data on deforestation for the countries of the Congo basin. Although the results confirm the existence of scale and composition effects, the impact of the technique effect is contrary to the predictions of theory. These results show that there is no inverted U-shaped between gross domestic product (GDP) and deforestation in the Congo Basin as predicted in the theoretical literature.

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1. Introduction

The environmental effects of economic growth have received a growing attention in recent years (see for example Grossman and Krueger, 1994; Cropper and Griffiths, 1994; Selden and Song, 1994; Shafik, 1994; Copeland and Taylor, 2004; Stern, 2004; Dasgupta et al., 2006; Apergis, 2016; Fotiset et al., 2017; Shahbaz et al., 2017). The decomposition of these effects into scale, composition and technique effects by Grossman (1995) and adopted by Copeland and Taylor (2004) and Copeland and Taylor (2006) is important in the determination of the level of pollution and use of natural resources. This decomposition stipulates that: Firstly, as agriculture intensifies, the population increases and that the industrial sector becomes more developed, production requires more inputs and this accelerates the rate of extraction of natural resources and increases the level of pollution. Economic growth therefore has a scale effect which has a negative impact on the environment. Secondly, growth has a positive or negative effect on the environment thanks to the composition effect. In fact, if the economy evolves towards an averagely «cleaner» («dirtier») productive structure, the emission of polluting substances and degradation drop («increase»). Finally, if «cleaner» production techniques replace the «dirtier» techniques, the emission of polluting substances and degradation drops because of the technique effect.

In the economic literature, the combination of these three effects generates an inverted U shaped relationship known as the Environmental Kuznets curve (EKC)[1] (see for example Grossman, 1995; Tsurumi and Managi, 2010; Koirala and Mysami, 2015). According to this curve, at the macroeconomic level, environmental pollution increases for low levels of income and this relationship falls as from a given threshold (turning point).

Authors like Grossman and Krueger (1991); Grossman and Krueger (1994); Harbaugh et al., (2002); Azomahou et al., (2005) focus on pollution. Others on the other hand focus on the reduction of natural resources defined as the different mineral or biological resources necessary to the life of mankind and his economic activities (see for example Koop and Tole, 1999 Dietz and Adger,2001; Bhattarai and Hammig, 2001; Pallab et al., (2004);Van and Azomahou, 2007; Arcand et al., 2008; Tsurumi and Managi, 2010).

This study falls under the extension of studies on the reduction of the natural resources by taking into account the three structural effects of the decomposition of Grossman (1995). The originality of this work comes from the fact that it focuses on deforestation. To our knowledge, no study has analyzed the three structural effects of Grossman's decomposition on deforestation.

The empirical analysis based on this theoretical model uses data on deforestation for the countries of the Congo basin. The choice of this region is justified by several factors: on the one hand, the forest of the Congo basin is the second largest contiguous block of tropical forest in the world. It makes up approximately 70 % of the forest cover of Africa (of the 530 million hectares of the Congo basin, 300 million is covered by forests). More than 99% of this forest consists of primary or naturally regenerated forests (unlike plantations) and 46% are low altitude dense forests (FAO, 2010). In all the forest rich countries of the Congo basin, except for the Central African Republic, the dense forests represent the largest ground cover (de Wasseige et al., 2012). In addition, these forests render invaluable ecological services at the local, regional and world levels. The local and regional ecosystem services in the Congo basin include the maintenance of the hydrological cycle (quantity and quality of water) and a significant control of floods in areas of high rainfall. The biodiversity of the forest of the

[1]The Environmental Kuznets curve is inspired from the work of Simon Kuznets. The idea being that initially, economic growth tends to worsen the inequalities in income, but beyond a certain threshold of GDP per capita, the trend is reversed so that the differences in income decrease.

Congo basin provides wood, non-wood forest products, food and drugs to millions of people. The additional regional advantages include the regulation of the climate on a regional scale which increases the resilience to the effects of climate change. Healthy forest ecosystems facilitate cooling at a regional level through evapotranspiration and constitute a natural buffer against the variability of the regional climate (West et al., 2011; Chapin et al., 2008).
The results of this study highlight the negative impact of the scale effect and the positive impact of the effect of composition on the forest cover of the countries of the Congo basin. Concerning the technique effect, the results show that this effect increases deforestation, which is against the predictions of theory.
The rest of this study is organized as follows: section 2 is devoted to the presentation of the Grossman decomposition (1995) into scale, composition and technique effects. In the third section, we present the data, variables and their descriptive statistics. Section 4 presents the econometric model and section 5 is devoted to the empirical results. Finally, section 6 concludes the study and summarizes the lessons from this study.

2. The Grossman decomposition

Based on certain macroeconomic principles, some theoretical analyses already more or less considered the supply side determinants of environmental pollution and studied the structural explanation of the formation of the Environmental Kuznets curve (Antweiler et al., 1998; 2001; He, 2005). According to Grossman (1995), the two phases of the EKC can be explained by three effects of development on the environment: the scale, composition and technique effects. Brock and Taylor (2004) bring out these structural determinants in the following equation:

$$D = \sum_{i=1}^{n} a_i s_i y \quad (1)$$

Where D represents the total reduction in resources caused by the n sectors of the economy, a_i is the intensity of the reduction, i.e. the average quantity of resources reduced for each unit of output in the sector i given by $a_i = \frac{D_i}{y_i}$. $s_i = \frac{y_i}{y}$ represents the weight of sector i in the national product (we thus have $\sum_{i=1}^{n} s_i = 1$) and y the national income. According to this equation, the total reduction of the resource can be represented by the product of the total GDP (Y) and the average intensity of reduction by sector weighted by the ratio of the GDP of each sector in the economy ($\sum_{i=1}^{n} a_i s_i$).

If the resource is renewable (fishery, forestry, etc…), the equation (1) becomes:

$$\dot{D} = \sum_{i=1}^{n} a_i s_i y - nD \qquad n > 0 \quad (2)$$

$$=> \dot{D} + nD = \sum_{i=1}^{n} a_i s_i y \quad (3)$$

where $\dot{D}$ is the total reduction and n the rate of regeneration of the natural resource.

Writing the net reduction in the resource as $D_N = \dot{D} + nD$, we obtain:

$$D_N = \sum_{i=1}^{n} a_i s_i y \quad (4)$$

It is possible to obtain the rate of increase in the net reduction of this resource. In fact, by differentiating equation (4) with respect to time, we obtain the Grossman decomposition:

$$\widehat{D} = \hat{y} + \sum_{i=1}^{n} \pi_i [\hat{a}_i + \hat{s}_i] \tag{5}$$

with $\pi_i = \frac{D_i}{D}$ which is the share of reduction by sector *i* in the total reduction.

Where $\hat{x} = \frac{[dx/dt]}{x}, x \epsilon \{ \mathrm{D}, a, s, Y)$

From equation (5), we obtain:

$$\widehat{D} = \hat{y} + \sum_{i=1}^{n} \pi_i \hat{a}_i + \sum_{i=1}^{n} \pi_i \hat{s}_i \tag{6}$$

This decomposition brings out three structural effects:

- Scale effect

$\hat{y}$ denotes the scale effect which summarizes the fact that if the technology and the structure of production remain unchanged, that is to say if $\widehat{a}_i = 0$ *and* $\hat{s}_i = 0$, then: $\widehat{D} = \hat{y}$: an increase in economic activity is accompanied by an increase in the degradation of the resource. Economic growth and the respect of the environment are thus incompatible (Nourry, 2007).

- Composition effect

This effect is related to international specialization. In order to separate this effect, we suppose that $\hat{y} = 0$ and $\widehat{a}_i = 0$, which enables us to write:

$$\widehat{D} = \sum_{i=1}^{n} \pi_i \, \hat{s}_i$$

Consequently, degradation drops if the economy evolves from an industrial sector intensive in the use of natural resources to sectors intensive in services, technology and human capital.

- Technique effect

The technique effect takes into account the variation of the level of degradation per unit of good produced. We suppose here that $\hat{y} = 0$ and $\hat{s}_i = 0$, that is to say economic activity and the structure of production are fixed. In this case, we have:

$$\widehat{D} = \sum_{i=1}^{n} \pi_i \hat{a}_i$$

Consequently, if $\widehat{a}_i < 0$, that is to say if the techniques of production become cleaner, degradation per monetary unit of production drops and the technique effect leads to a reduction in the destruction of natural capital.

3. Data and variables

The Central African Sub-region (COMIFAC[2] area) is made up of 10 countries: Burundi, Cameroon, the Republic of Congo, the Central African Republic, the Democratic Republic of Congo, Gabon, Equatorial Guinea, Rwanda, Sao Tome and Principe and Chad. Within the framework of EDF (State of the Forests), the Congo basin is often limited to the six forest countries of Central Africa (Cameroon, the Central African Republic, the Democratic Republic of Congo, Gabon, Equatorial Guinea and Congo) which belong to the Congo Basin Forest Partnership (CBFP) (see for example Wasseige et al., 2012; Megevand et al., 2013). The sample which we retain in this study is thus made up of the 06 forest countries above and cover a period going from 1990 to 2010.

The variable that we seek to explain is the rate of deforestation at the time *t,* defined in the following manner:

$$\mathbf{DF}_{it} = -\frac{\mathbf{F_{it}} - \mathbf{F_{it-1}}}{\mathbf{F_{it-1}}}$$

Where F_{it} is the forest area of country i at the year t. To calculate this rate, we use the data of the FAO which is the most exhaustive currently available and are used internationally. This can be shown through two examples. Firstly, the forest data of the FAO are used as indicator for the monitoring of progress towards the Millennium Development Goals adopted by the United Nations. Secondly, they are used by the Intergovernmental Panel on Climate Change (IPCC) which is charged by the United Nations with evaluating the consequences of global warming. However, this data has certain limits, particularly regarding its collection because they are the governments of the countries themselves who transmit them to the FAO.

We thus obtain a total sample of 120 observations (T = 20, 1990 – 2010). The following paragraph presents the analysis of the descriptive statistics of the various data used in the econometric models.

Antweiler et al., (2001) analyze the determinants of environmental degradation and decompose the latter into scale, composition and technique effects. They use the GDP per square kilometer as indicator of the scale effect, the income per capita as indicator of the technique effect and the capital-labour ratio as indicator of the composition effect. Panayotou (1997) and Tsurumi and Managi (2010) use the GDP per square kilometer as indicator of the scale effect, the income per capita as indicator of the technique effect and the share of industry in the GDP as indicator of the composition effect. In the case of deforestation, Tsurumi and Managi (2014) show that the degree of commercial openness or the comparative advantage of the country (capital-labour ratio) can be used as an indicator of the composition effect. We follow proxies of previous studies for scale, technique, and composition effect. We use variables for which data are available.

In this study, we use the GDP per square kilometer as an indicator of the scale effect ($Scale$). We expect a positive sign for this effect. The income per capita (expressed in constant 2005 USD) is used to measure the technique effect ($Technique$) and the capital-labour ratio as an indicator of the composition effect ($Composition$). An implicit hypothesis for this effect is that the more a country uses capital intensively, the less it should destroy forests. We thus expect a negative sign for the capital-labour ratio. The first two variables are extracted from the indicators of the World Development Indicators (WDI, 2013), which is usually the database used in the literature on the subject, while the capital-labour ratio is extracted from the Penn World Table 4.0.

Table 1. Descriptive statistics

[2]Central African Forest Commission.

Variables	Definition of the variables	Observations	Means	Standard error	Min	Max
DF	Deforestation rate (%)	120	.0032743	.0036514	0	.010926
Scale	GDP per capita (1000)	126	5.626262	7.41528	.247889	31.5185
Composition	Capital-labor ratio	115	11171.58	19397.28	745.8442	63432
Technic	GDP per Km^2	126	76783.49	149016.3	37397	765310

Source: author going from the data of FAO, the WRI and Penn World table 4.0. All the income variables are expressed in 2005 PPP constant international $.

Table 1 shows the descriptive statistics of the variables economic growth and the rate of deforestation. We notice that the average rate of deforestation of the sample over the period of study (1990-2010) is 0.33 %; the minimum value of the average rate of deforestation is recorded in Gabon (0 %), while the maximum is in Cameroon (1.09 %). Concerning the indicators of economic growth, the GDP per capita for the set of countries is on average equal to 5,626 $. Equatorial Guinea is the country which witnessed the highest level of GDP per capita thanks to the export of the raw materials (31,518 $ in 2009). The Democratic Republic of Congo is the country which witnessed the lowest level of GDP per capita (247 $ in 2002). Also, the GDP per km^2 amounts on average to 76,783 $ for the set of countries and the capital-labour ratio stands at 11,171$ on average.

4. Empirical model

In the literature regarding environmental Kuznets curve, parametric functional forms (of quadratic and cubic polynomials) of the relationship between deforestation and per capita real GDP have been used to verify the existence of turning points. Although there is an abundance of literature on this subject, its econometric applications have been criticized because of a lack of robust econometric specifications (Stern 2004). In response to these claims, some authors have used semiparametric or nonparametric specifications to reexamine these results because they are more flexible than popular parametric functional forms (for a review, see Azomahou et al. 2006). In our study, we use a nonparametric approach.

The structural analysis can be represented by the following equation:

$$\mathrm{DF}_{it} = \alpha_i + \beta_1 Scale_{\ it} + \beta_2 Composition_{it} + \beta_3 Technique_{it} + \varepsilon_{it} \qquad (7)$$

where the different β are the parameters of interest, the indices i and t respectively indicate the country considered and the year of observation.

In the literature on nonparametric estimates, two main approaches are distinguished: Kernel regressions and local (LOESS and LOWESS) regressions. It should be noted that the objective of nonparametric regression is not to estimate coefficients or to measure the degree of co-variation between the variables but to obtain a better adjustment of the scatter plot showing the relationship between the two variables.

The Kernel estimator of the link function evaluated at the point (x_0) written $\widetilde{f}(x_0)$ developed by Nadaraya (1964) and Waston (1964) is given by:

$$\widetilde{f}(x_0) = \frac{\sum_{i=1}^{N} K(\frac{x_t - x_0}{\lambda}) y_i}{\sum_{i=1}^{N} K(\frac{x_t - x_0}{\lambda})},$$

where $K(\cdot)$ denotes a Kernel function, λ is a parameter of smoothing (bandwidth parameter) and N the sample size. Thus, for any point $x_{i,}\ i\,\epsilon[1, \dots, \mathrm{N}]$, the link function is defined as the weighted sum of the observations y_i whose weights $w_i(x_0)$ depend on (x_0). For $w_i(x_0) = \frac{K(\frac{x_t-x_0}{\lambda})}{\sum_{i=1}^{N} K(\frac{x_t-x_0}{\lambda})}$ we have the reduced form of the link function which is written as follows:

$$\tilde{f}(x_0) = \sum_{i=1}^{N} w_i(x_0) y_i.$$

One of the reasons for using Kernel approach is that except for the uniform kernel function, the use of other functions does not really change the results. However, the kernel estimation poses the problem of the choice of the parameter of smoothing λ. Another important problem with the Kernel regression is the lack of robustness for extreme values of the exogenous variable. An alternative solution which is more robust for extreme values consists in using local regressions.

The objective of local regression consists in approximating the function only in the neighborhood of each point x_0. The early methods of local regression LOESS or «Locally Weighted Running-Line» were proposed by Cleveland (1979). In fact, if it is supposed that the approximation of $f(\cdot)$ is done by a linear function whose general form is: $\tilde{f}(x_0) = \hat{a}(x_0) + \hat{b}(x_0)x_0$. The objective here is to determine $\hat{a}(x_0)$ and $\hat{b}(x_0)$ while minimizing at each moment, as for the method of OLS, the sum of the square S of the residuals in the neighborhood of x_0 in the following manner:

$$\{\hat{a}(x_0), \hat{b}(x_0)\} = \underset{\{\hat{a}(x_0), \hat{b}(x_0)\}}{\text{ArgMin}} \left[\sum_{x_i \epsilon V(x_0)} [y_i - a(x_0) - b(x_0)x_i]^2 \right] \tag{8}$$

The main difference with Kernel regression is that the value of $f(x_0)$ estimated is not a weighted average but a value given by a straight regression line. On the other hand, the LOESS method requires more time to calculate because for *N* observations, it is necessary to carry out *N* regressions. Within the framework of the LOESS regression, the parameter of smoothing λ makes it possible to determine the neighborhood $V(x_0)$ in which the regression must be carried out using the following ratio: $\lambda = \frac{dim[V(x_0)]}{N}, \forall\, x_0$. Notice that for λ tending towards 0, the estimator of the link function will not be very precise (large variance) given the narrow width of the neighborhood. On the other hand, for values of λ close to 1, the link function is linear and we find ourselves within the framework of an ordinary regression.

Cleveland and Devlin (1988) propose an extension of LOESS regressions by weighting each point by a kernel type weight function: these are the LOWESS «Locally Weighted Regression and Smoothing Scatterplots» models. Thus, we can say that LOWESS regressions are a synthesis of Kernel type and LOESS models. We easily notice that for $K(\cdot) = 1$, the LOWESS regression is identical to the LOESS regression. The estimates $\hat{a}(x_0)$ and $\hat{b}(x_0)$ of the LOWESS models are determined as follows:

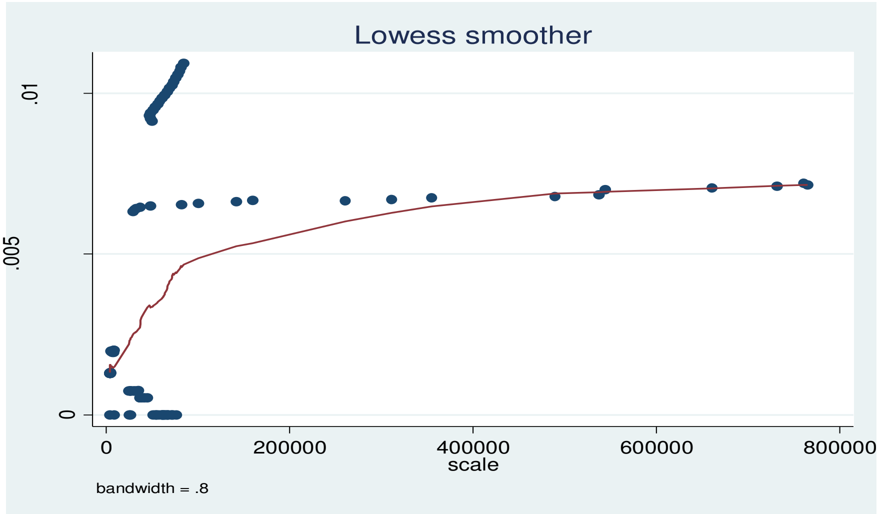
$$\{\hat{a}(x_0), \hat{b}(x_0)\} = \underset{\{\hat{a}(x_0), \hat{b}(x_0)\}}{\text{ArgMin}} \left[\sum_{x_i \epsilon V(x_0)} [y_i - a(x_0) - b(x_0)x_i]^2 K(\frac{x_i - x_0}{\lambda}) \right] \tag{9}$$

We do a nonparametric analysis of the relationship between the rate of deforestation and economic growth through LOWESS type nonparametric regressions.

5. Analyses of results

The nonparametric (LOWESS) analysis shows a positive slope of the scale effect (see graph No. 1). This positive slope of the scale effect implies a negative impact of economic expansion on deforestation. This result is thus in line with the conclusions obtained from studies at the international level. This is explained by the fact that the economic expansion of the countries of the Congo basin of is carried out mainly through the sector of forestry development which historically remains one of the main contributors to the GDP. The forestry sector plays an even more important role in the Congo basin. With the spectacular development of the oil sector in several countries of the Congo basin during the last decade, the relative contribution of the forest sector to the GDP decreased. However, we find signs that show that in Gabon, the planned fall in the production of oil during the next decade can lead to a resumption of the growth of forestry development and export (Megevand et al., 2013).

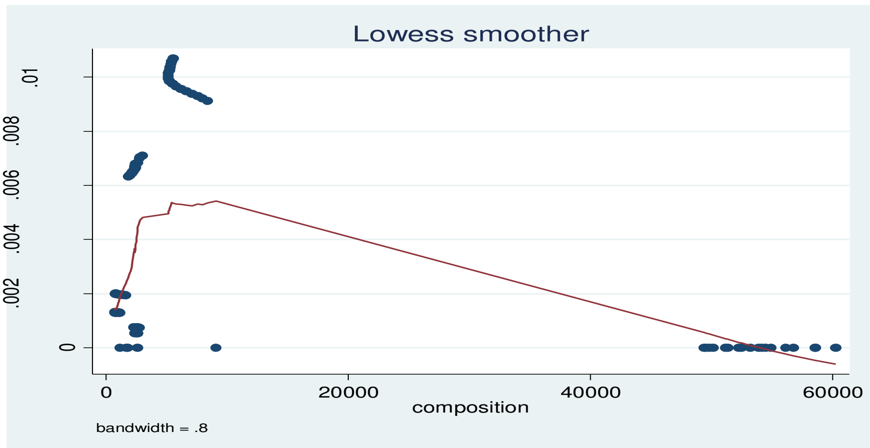
Graph No. 1: Nonparametric relationship between deforestation and the GDP per km²



Source: author going from the data of FAO, the WRI and Penn World table 4.0.

We also easily observe an evolution in two sequences of the relationship between deforestation and the variable *Composition* (graph No. 2): initially, the link between the capital-labour ratio and deforestation is characterized by a positive slope i.e. a rise of the level of the capital-labour ratio is associated with an increase in the rate of deforestation. In the second phase, the capital intensity reverses this relationship.

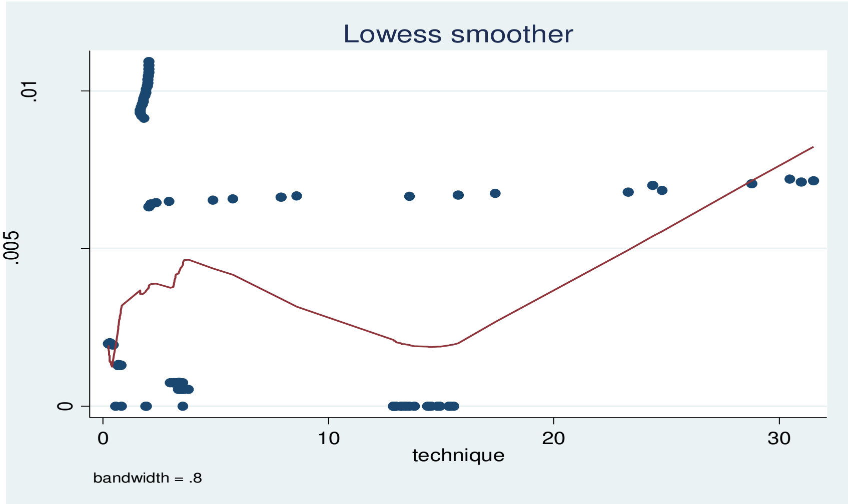
Graph No. 2: Nonparametric relationship between the capital-output ratio and deforestation.



Source: author going from the data of FAO, the WRI and Penn World table 4.0.

With regards to the technique effect, although it is nonlinear, it does not follow the same trend as the other variables of economic growth. Contrary to the scale effect which shows a linear relationship with deforestation, the technique effect portrays an «N» shaped relationship at the level of the regressions, showing that an improvement in the techniques of production has a negative impact on the forest cover of the Congo basin (graph No. 3). An improvement in the technical efficiency, although it leads to an increase in agricultural output and an improvement in the techniques of wood cutting and the use of trees in a much more efficient manner to produce wood, also generates an increase in the capacities of transformation of wood in the Congo basin and an extension of arable land which counterbalances the positive effects of the techniques of wood cutting and agricultural production. The net effect is an increased pressure on the forest cover of the area. This unexpected result which is contrary to theoretical predictions can be explained by the weaknesses in the legal environment. Lumber wood for example, from its production to its sale, passes between the hands many officials (customs, police, local politicians, transport authorities…) who are likely to request bribe to let the product continue the production and marketing process (Kishor and Damania, 2007; Brown, 2010).

Graph No. 3: Nonparametric relationship between deforestation and the GDP



Source: author going from the data of FAO, the WRI and Penn World table 4.0.

6. Conclusion

This study has as objective to examine the theoretical and empirical aspects of the Environmental Kuznets curve for natural resources. We first decompose the structural factors into three effects (scale, composition and technique) enabling us to lay emphasis on the optimistic scenario of the protection of natural resources following the economic growth of the countries considered.

Using a nonparametric regression, we confirm the theoretical impact of the scale and composition effects on deforestation in the Congo basin. On the other hand, the improvement of the techniques of production has a negative effect on the forest cover of the Congo basin. This is against the predictions of theory. Without the implementation of a combination of policies and measures to accompany the follow-up and monitoring on the field, an improvement in the techniques of production will cause a significant rise in deforestation in the Congo basin. This reveals the need for the reinforcement of collective organizations (NGOs, Action networks etc.) in the countries of the Congo basin.

References

Antweiler, W., Copeland, B. R. and M.S. Taylor. (1998) "Is Free Trade Good for The Environment?" NBER number 6707

Antweiler, W., Copeland, B. R. and M.S, Taylor. (2001) "Is Free Trade Good for The Environment?" *American Economic Review* **4**, 877-908.

Apergis, N. (2016) "Environmental Kuznets curves: New evidence on both panel and country-level CO2 emissions" *Energy Economics*, **54**, 263-271.

Brock W.A., and S. Taylor (2004) Economic Growth and the Environment: a Review of Theory and Empirics NBER working paper number 10854

Brown, M.L. (2010) "Limiting corrupt incentives in a global REDD regime" *Ecology Law Quarterly* **37**, 237-268

Chapin, F.S., Randerson J., McGuire, A.D, Foley, J and C. Field (2008) "Changing feedbacks in the climate-biosphere system" *Frontiers in Ecology and the Environment* **6**, 313–320.

Copeland, B.R and M.S. Taylor (2004) "Trade, Growth, and the Environment" *Journal of Economic Literature* **42**, 7–71.

Copeland B. R et Taylor M. S., (2006) "*Trade and the Environment: Theory and Evidence*" Princeton NJ: Princeton University Press.

Cropper, M and C. Griffiths (1994) "The interaction of population growth and environmental quality" *American Economic Review* **84**, 250–254.

Dasgupta, P., Hamilton, K., Pandey, K.D and D. Wheeler (2006) "Environment during growth: accounting for governance and vulnerability" *World Development* **34**, 1597–1611.

de Wasseige, C., P. de Marcken, N. Bayol, F. Hiol Hiol, Ph. Mayaux, B. Desclée, R. Nasi, A. Billand, P. Defourny, and R. Eba'a Atyi. (2012). « *Les forêts du bassin du Congo - État des forêts 2010* ». Luxembourg : Office des publications de l'Union européenne.

Dietz S and N. Adger (2001) "Economic Growth, Biodiversity Loss and Conservation Effort", University of New Anglia, Centre for Social and Economic Research on the Global Environment *working paper ECM 01-03*.

Fotis P., Karkalakos S and D. Asteriou (2017) "The relationship between energy demand and real GDP growth rate: The role of price asymmetries and spatial externalities within 34 countries across the globe" *Energy Economics* **66**, 69-84.

Grossman, G. (1995) “Pollution and growth: What do we know?” In Goldin and Winter (eds.). The *Economics of Sustainable Development*, Cambridge University Press, 1995.

Grossman, G and A. Krueger (1991) “Environmental Impacts of a North American Free Trade Agreement” NBER working paper number 3914.

Grossman, G and A. Krueger (1995) “Economic growth and the environment” *Quarterly Journal of Economics* **60**, 353–377.

Harbaugh, W.T., Levinson, A and D.W. Molloy (2002) “Reexamining the Empirical Evidence for an Environmental Kuznets Curve” *The Review of Economics and Statistics* **84**, 541-551.

He J. (2005) « Impacts environnementaux de l’industrialisation et du commerce international en chine : cas de l’émission industrielle de SO_2 », Ph.D Thesis University of Auvergne Clermont 1.

Kishor, N and R. Damania (2007) “Crime and justice in the Garden of Eden: Improving governance and reducing corruption in the forestry sector” *In the Many Faces of Corruption: Tracking Vulnerabilities at the Sector Level*, edited by J.E. Campos and S. Pradhan. Washington, DC. The World Bank.

Koirala, B.S and R.C. Mysami (2015) “Investigating the effect of forest per capita on explaining the EKC hypothesis for CO2 in the US” *Journal of Environmental Economics and Policy* **4**, 1-11.

Koop, G and L. Tole (1999) “Is there an environmental Kuznets curve for deforestation?” *Journal of Development Economics* **58**, 231-244.

Kuznets, S (1955) “Economic Growth and Income Inequality” *American Economic Review* **49**, 1-28.

Nadaraya, E. (1964) “On Estimating Regression” *Theory of Probability and its Applications* **9**, 141-142.

Nourry, M. (2007) « La croissance économique est-elle un moyen de lutte contre la pollution ? » *Revue française d'économie* **21**, 137-176.

O’Connor, D. (1994) « La gestion de l’environnement dans les pays en voie d’industrialisation rapide : leçons tirées de l’Asie de l’Est » *Centre de Développent de l’OCDE, Paris.*

Selden, T and D. Song (1994) “Environmental quality and development: Is there a Kuznets curve for air pollution emissions?” *Journal of Environmental Economics and Management* **27**, 147–162.

Shahbaz, M., Shafiullah, M., Papavassiliou, V.G and S. Hammoudeh (2017) “The CO2-Growth nexus revisited: A nonparametric analysis for G7 economies over nearly two centuries” *Energy Economics*, doi:10.1016/j.eneco.2017.05.007

Shafik, N. (1994) “Economic development and environmental quality: an econometric analysis” *Oxford Economic Papers* **46**, 757–773.

Stern, D.I. (2004) “The Rise and Fall of the Environmental Kuznets Curve” *World Development* **32**, 1419-1439.

Tsurumi, T and S. Managi (2010) “Decomposition of the environmental Kuznets curve: scale, technique, and composition effects” *Environmental Economics and Policy Studies*, **11**, 19–36.

Tsurumi, T and and S. Managi (2014) “The effect of trade openness on deforestation: empirical analysis for 142 countries” *Environmental Economics and Policy Studies* **16**,305–324.

Waston, G. (1964) « Smooth Regression Analysis », Sankhya: *The Indian Journal of Statistics Series* A **26**, 359-372.

West, P.C., Narisma, G., Barford, C., Kucharik C and J. Foley (2011) “An alternative approach for quantifying climate regulation by ecosystems » *Frontiers in Ecology and the Environment* **9**, 126–133.