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***Etudes et Documents***

E 2012.16

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*avril 2012*

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La série des *Etudes et Documents* du CERDI est consultable sur le site :
http://www.cerdi.org/ed

Directeur de la publication : Patrick Plane

Directeur de la rédaction : Catherine Araujo Bonjean

Responsable d'édition : Annie Cohade

ISSN : 2114-7957

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## Highlights

- We carry out a meta-analysis of Environmental Kuznets Curve (EKC) studies for deforestation.
- We analyze the results of 71 studies, offering a total of 631 estimations.
- We investigate the incidence of choices made by authors (econometric strategy, deforestation measure, temporal coverage, geographical area, measure of economic development…) on the probability of finding an EKC.
- After a phase of work corroborating the EKC, we find a turning point after the year 2001.

## Abstract

Although widely studied, deforestation remains a topical and typical issue. The relationship between economic development and deforestation is still at stake. This paper presents a meta-analysis of Environmental Kuznets Curve (EKC) studies for deforestation. Using 71 studies, offering 631 estimations, we shed light on why EKC results differ. We investigate the incidence of choices made by authors (econometric strategy, deforestation measure, temporal coverage, geographical area, measure of economic development…) on the probability of finding an EKC. After a phase of work corroborating the EKC, we find a turning point after the year 2001. Building on our results, we conclude that the EKC story will not fade until theoretical alternatives will be provided.

## Keywords

Meta-Analysis; Environmental Kuznets Curve; Deforestation, Development

## JEL Codes

C12, C83, Q23, O13

Mark Twain: "The report of my death was an exaggeration"

*New York Journal* 2 June 1897

## 1. Introduction

One important question which is still at stake, even more in an economic crisis context, is whether environmental and economic objectives are compatible subjects. This question gets high resonance in the literature devoted to the Environmental Kuznets Curve (EKC) for deforestation which is a subject of confrontation between optimistic and pessimistic views of development (Carson 2010). This literature has gained considerable expansion in economics as well as in natural sciences (Mather et al. 1999). From the 1990s onwards, numerous studies following the idea of (Grossman & Krueger 1995) tested an EKC for deforestation.

Studying EKCs for deforestation is an important matter for two reasons.

First, forest depletion has been given increasing attention especially with the recognition of the role of forests in the global carbon cycle. Recent developments in the literature on climate change put forward the potential role of forests in climate change mitigation (N. H. Stern 2007). The impetus was given to the so-called "Reducing emissions from deforestation and forest degradation" (REDD) device first proposed for negotiation at the Montreal UNFCCC CoP held in 2005. The Bali Road Map adopted in 2007 went beyond with the REDD+ concept by enhancing other objectives such as sustainable management of forests and valuation of forests carbon stocks (Angelsen, Brockhaus, et al. 2009; Angelsen, Brown, et al. 2009; Engel & Palmer 2008). As pointed out by (Geist & Lambin 2001) the role of forests in mitigating global environmental threats such as climate change and biodiversity erosion is a research imperative and has been motivating considerable efforts to the understanding of patterns and causes of the deforestation process and *in fine* to the derivation of policy implications (Angelsen & Kaimowitz 1999).

Second, EKC has drawn attention from scholars for several years (e.g. (Ma & D. I. Stern 2006). Studying EKCs for deforestation may therefore offer an interesting case in the methodology of economics from a sociological point of view. According to (Kuhn 1996), scientists share common beliefs and practices which circumscribe the "normal science". They are often reluctant to diverge from them since they are most of the time evaluated and published according to rules widely accepted within the normal science. EKCs seem to belong to such a set of practices. It is indeed rather striking that several researchers seem to consider it as "econometrics as usual" i.e. a relevant hypothesis which helps understanding environmental degradation and for instance the deforestation process. Other researchers have conducted critical reviews and forcefully argued in favour of its obsolescence (Levinson 2002; D. I. Stern 2004). Thus there seems to be a discrepancy between, on the one side, researchers who dismiss EKCs and, on the other side, scientists who consider that EKCs are relevant. Among the latter, the EKC is still presented as one of the hypotheses explaining the forest transition process (Barbier et al. 2010; Rudel et al. 2005; Mather 1992).

The objective of this paper is to examine why scholars get accustomed to the EKC for deforestation or whether they have "objective" reasons to dismiss it. In contrast with existing studies or critical surveys on the EKC for deforestation, we propose to address the subject with a meta-analysis which can be considered as an attempt to identify "wheat from chaff" (Stanley 2001) i.e. identify a set of reasons that favour or falsify empirical evidences of EKCs for deforestation.

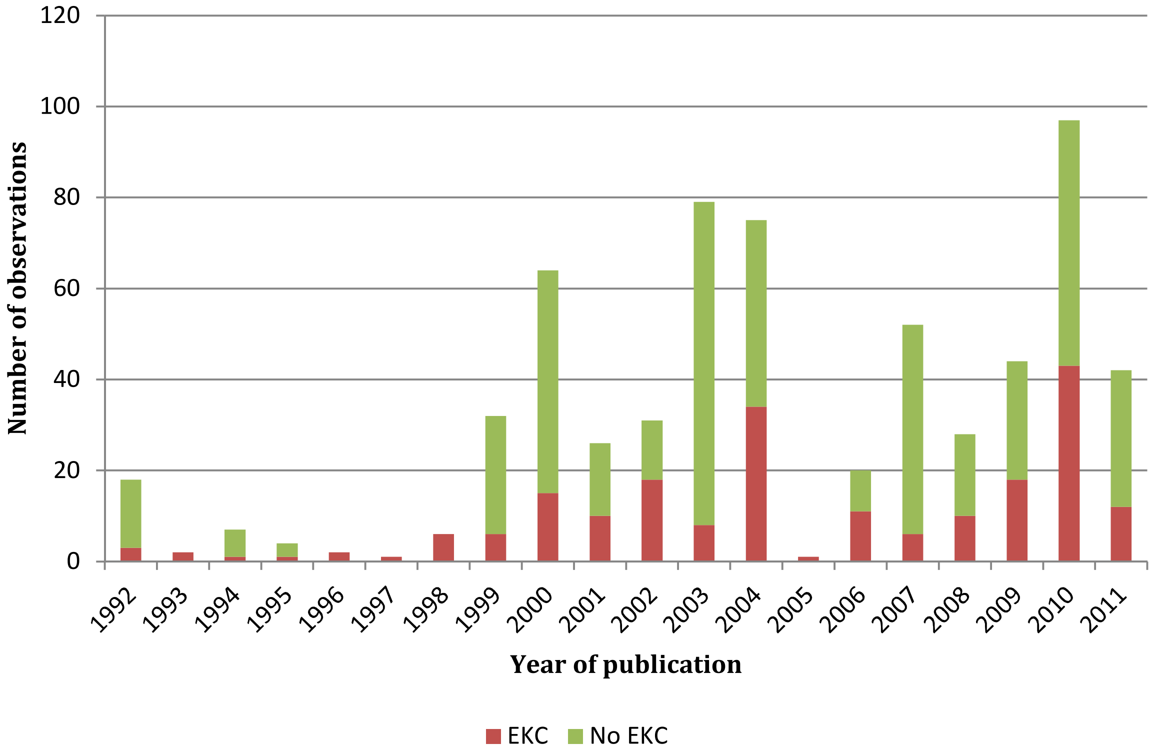
The rest of the paper is organised as follows. Section 2 presents the debate in the literature on the EKC for deforestation. Section 3 further justifies the use of meta-analysis. Section 4 is devoted to the construction of the database. Section 5 develops on the empirical strategy and the econometric results. Section 6 discusses the results and Section 7 concludes.

## 2. Contrasted Premises and Results

The story with EKCs started with (Grossman & Krueger 1995) and (Panayotou 1993). According to (Beckerman 1992, p.482) : "[…] there is clear evidence that, although economic growth usually leads to environmental deterioration in the early stages of the process, in the end the best - and probably the only - way to attain a decent environment in most countries is to become rich." This optimistic premise was later mitigated by the (Arrow et al. 1996) assertion according to which economic growth is not a sufficient condition for getting environmental improvements or curbing environmental degradation. It is even more doubtful to find EKCs when stock variables with strong potential feedback are expected in, for instance, ecosystems such as tropical forests.

The economic literature provides theoretical underpinnings for an EKC. Many of them model pollutants emissions – income relationships (Andreoni & Levinson 2001; Xepapadeas 2005). (Munasinghe 1999) develops a static model showing that appropriate policy measures (i.e. removal of subsidies on timber exports) could help alleviating the pressure on tropical forest stocks and thus "tunnelling" through the EKC for deforestation. Theoretical explanations of EKCs for deforestation were also developed with the so-called poverty-environment hypothesis as opposed to the capital or frontier model (Geist & Lambin 2001; Rudel & Roper 1997). The contention that economic development has a negative (positive) impact on deforestation is suggested by the former (latter). Theoretical models explaining agricultural land expansion may also be compatible with an EKC for deforestation (Barbier 2001). It is however worth to notice that several authors are rather unsatisfied with the current theoretical literature on the EKC for deforestation and call for further developments (Roy Chowdhury & Moran 2012).

**Figure 1. Empirical analyses of EKCs for deforestation**




Source: Own calculations. See Section 4 for more details on the construction of the database. One observation represents one estimation.

Early econometric results (Shafik & Bandyopadhyay 1992) and further ones on the existence of an EKC for deforestation were not conclusive. More than a half over more than 600 estimations published since 1992, do not corroborate the EKC (Figure 1). This bulk of mixed results seems to have encouraged several authors against the EKC. One of the most serious attack against EKCs was provided by (D. I. Stern 2004; Levinson 2002) with close titles. Critical reviews of EKC focusing on deforestation raised several empirical shortcomings which may have impacted the EKC for deforestation corroboration. As mentioned by (Koop & Tole 1999), FAO databases were mostly used. Early FAO databases were from FAO production yearbook. Supposedly, more recent ones from Forest Resources Assessment published in most recent studies have greater reliability. Irrelevant econometric methods are also put forward. Early estimates relied on cross-section data which imply restrictive hypotheses (Dinda 2004; Koop & Tole 1999). More recent studies thus implemented panel data or more generally pooled cross sectional time series data. It may be worth to examine whether improvements made in econometric devices had an impact on the existence of an EKC for deforestation.

One may thus be confused between on the one side, Stern's contention according to which "most of the EKC literature is econometrically weak" (D. I. Stern 2004, p.1420) and empirical analyses still relying on or testing the EKC for deforestation. But one may understand the situation while remembering (McCloskey 1983). It seems that economists need more than statistical tests to get rid of a hypothesis like the EKC. Would they give weight to the rhetoric surrounding the EKC? In this paper, we want to check whether characteristics of publications dealing with EKCs for deforestation play a role in their corroboration. We argue that conducting a meta-analysis of EKCs for deforestation equations can contribute to their critical assessment.

## 3. The Use of Meta-Analysis

A meta-analysis produces, through a set of statistical techniques, an overall summary of empirical knowledge on a specific topic. "Meta-analysis is the analysis of empirical analyses that attempts to integrate and explain the literature about some important parameter" (Stanley & Jarrell 1989, in (Stanley et al. 2008, p.163). "It can explain the excess study-to-study variation typically found in empirical economics, uncover the trace of statistical power that is associated with a false theory, and see through the distortion of publication selection and misspecification biases" (Stanley 2005, in (Stanley et al. 2008, p.163).

Before the 90's, scientists synthesised the results of the research literature through the use of narrative review. However, the limit of this method was quickly reached with the increase in the amount of information available. Indeed it seems inconceivable using this method to successfully synthesize the results of dozens of studies which, moreover, are conflicting in their results. (Hunter & Schmidt 2004) explain that narrative surveys developed the so-called "myth of the perfect study": a researcher may be convinced that some studies suffer from methodological flaws and exclude them from the review; another one may consider different methodological flaws. Hence, idiosyncratic ideas may lead one to reduce available literature on a topic from 100 studies to 10 and another one from 100 to 50.

Meta-analysis allows to address the inherent limitations of the traditional narrative review by providing a more effective approach (Stanley 2001); it allows to set up an evaluation with several measures of "outcome"; it permits the use of moderators: some characteristics of the samples used in different studies influence the results obtained. Moreover, meta-analysis is a good tool for decision support because it helps in the assistance in planning, in the generation of new hypotheses, and eventually, prospective meta-analysis.

Research questions are often the subject of numerous studies leading to various controversies. As mentioned earlier, the EKC for deforestation is no exception, on the contrary, as shown in different reviews of the literature on the subject. Different opinions differ on the question of the existence of an EKC for deforestation and this, especially since empirical analysis validate and invalidate this hypothesis according to econometric models, measures of deforestation, study area, temporal coverage, etc. Since 1992, empirical work has been accumulated and we even see a significant increase in the number of studies since the 2000s (Figure 1). Finally, despite the abundance of empirical studies, it is difficult to propose clear recommendations arising directly from the relationship between economic growth and deforestation. Our approach, based on the meta-analysis, is complementary with respect to existing surveys (D. I. Stern et al. 1996; D. I. Stern 2004; Dinda 2004). Indeed, it allows us to statistically analyse the variation in results found between existing works and in particular to analyse the influence of choices made by the authors on their results (Stanley 2001).

There exists meta-analysis for EKC studies. These encompass however various environmental goods. (Cavlovic et al. 2000) performed a meta-analysis of 25 studies - 121 observations - with a focus on turning points. They cover 11 categories of environmental goods such as urban air quality or deforestation. Observations for deforestation represent only 6 % of their sample. The impact of deforestation on income turning points depends on the econometric specification of the meta-analysis. (Jordan 2010) analyses 255 articles - 373 observations - among which 8 % deal with deforestation. Results show no significant impact of deforestation on the probability of finding an EKC.

The operationalization of a meta-analysis is done by following specific steps. The first step is the formulation of the subject: what are the issues and objectives of the study (central questions we would like answers to) and what are the assumptions made. The second step is the overall design of the study: this is to clarify outcomes, populations, settings, criteria for inclusion and exclusion of studies. The third step is to specify the sampling plan, the units of observation and then begin the literature search. The fourth step is the extraction of data: it is directly applicable to studies that were selected for further analysis after the application of inclusion / exclusion criteria. The fifth step is the statistical analysis. As recommended by (Nelson & Kennedy 2008), we address relevant issues such as heteroskedasticity, the non-independence of regressions, the specification of the model, the non-normality of residuals and multicollinearity.

## 4. Construction of the Database

### 4.1. Sampling procedure and sample characteristics

This meta-analysis is based on 71 studies, offering 631 estimations.[1] In a meta-analysis, an important aspect of the work is to find studies that addressed the theme of the investigation. We conducted our research using academic databases such as "Science Direct", "Springer", "RePEc Ideas", "Mendeley", "Wiley", etc. The first step of this research was to enter keywords such as "Kuznets AND Deforestation", "Income AND Deforestation", "Development AND Deforestation", "Poverty AND Deforestation". Given that there are relevant studies which are not identified by bibliographic databases, in a second step we carried out a manual search and this by identifying journals and articles relevant to the topic. We then browsed these studies in order to identify new ones which have addressed closely the subject. A third step was necessary as we had to directly contact the authors since some studies are not accessible on the web. At the end of the research process, we got to build up an information base of nearly 102 items that we have then filtered through inclusion criteria.

At this stage, we selected eligibility criteria to be applied to the bibliographic database. In order not to bias the meta-analysis on subjective considerations, we tried to be broad in our inclusion criteria. First, we looked closely at the dependent variable

[1] The list of primary studies is available from the authors upon request (See Table A - 1 in the Appendix).

used in each estimation. Once done, we decided to retain all the measures relating directly to deforestation. At the end of this inclusion work, we have reached 71 studies that were used to build the database of this article.[2]

Every relevant estimation was carefully examined and the information was gathered to build the database. Accordingly, we surveyed all the information given by the authors related to the EKC (coefficients associated with variables of interest), the sample (size, geographical area …), the econometric method, control variables, and all information considered necessary to carry out this meta-analysis. In terms of coefficients and their sign, they were adjusted according to the nature of the dependent variable and depending on the outcome. For example, when the dependent variable is the rate of deforestation, to obtain an EKC, the coefficient of per capita GDP should be positive and negative for the squared GDP. By cons, if the dependent variable is the stock of forest, the hypothesis of an EKC is confirmed if the coefficient of GDP is negative and that of squared GDP is positive. Also to be as broad as possible we defined our null hypothesis whenever the estimated marginal effects of GDP and GDP squared had the expected signs at the 10% level.[3] We did not try to minimise this type I error since it is detrimental to the power of the test. In brief, we define our dependent variable as EKC which equals to 1 when the existence of the EKC for deforestation is corroborated and 0 otherwise.

[2] For instance were excluded from the sample studies analyzing biodiversity, the ecological footprint, land vulnerability or protected areas. Also studies focusing on households were excluded.

[3] The decision on the results was based on the significance of all coefficients of interest. For instance, in the quadratic model, as in most studies tests for joint significance were not performed, the model is considered significant if the two coefficients (i.e. per capita GDP and squared per capita GDP) are individually significant.

### 4.2. Moderator variables

At the end of this work, the database we had raw on hand included 631 observations and numerous differences, most of which focused on the explanatory variables used. Therefore for the sake of synthesis, these variables were grouped into classes. Table 1 presents the description and descriptive statistics of the variables. Next we shall discuss factors that may affect the income-deforestation relationship. These are the explanatory variables used in our model.

In view of the criticisms of the EKC literature, our variables of interest are the year of publication and the econometric technique.

Regarding the time period, variables are the year of publication of the study, the initial year of data, the final year of data. Differences between studies may reflect numerous issues such an academic trend, the increasing quality and availability of deforestation data, the mix of old and recent data or econometric requirements in peer-reviewed journals. For instance, (Jordan 2010) finds that the most recent year of publication is, the more likely to find an EKC decreases, while controlling for the nature of environmental degradation.

With respect to econometric techniques, as pointed out in critical reviews of EKCs, one may cast doubts on econometric techniques in early works. Advances in econometrics may make recent studies more credible than they were in the nineties. Several authors argued for instance that panel data regressions are more appropriate for analysing the EKC. Indeed, deforestation is a dynamic process therefore the nature of the relationship between income and deforestation should also be dynamic. If the time dimension is ignored, a spurious income-deforestation relationship could be observed. (Dinda 2004) argues that cross-section analysis is based on restrictive econometric assumptions as to admit the same constant. What is more, using panel data also allows for controlling for substantial time-invariant unobservable variables (such as countries physical characteristics or historical factors among many others). On top of that, the EKC theory was developed in an a-spatial framework. Hence, we could expect the inclusion of spatial dimension to alter the EKC hypothesis.

In addition to the variables of interest, we propose control variables or moderators. Concerning the measures of deforestation, we note that in early studies, the latter is not homogeneous. As part of this work 15 different measures are used. It is interesting to investigate whether these modify the income-deforestation relationship. In fact, some measures of deforestation are causes of the latter, as the expansion of agricultural land or infrastructures. (Geist & Lambin 2001) illustrate the differentiated effects of different causes of deforestation. We also believe relevant to include the geographical area; in fact growth path are different in developed and developing countries which can influence the occurrence of EKC and even more so that the samples of studies are based on recent data that do not capture development phases of developed countries. As for the measures of economic development, we observe some heterogeneity in the sample. However, there is no *a priori* on why and in what way such differences affect the occurrence of an EKC. Regarding the publication type, according to the aim of the study, one can expect different strategies of the authors, without compromising their neutrality. In particular, as Lindhjem (2007) finds a significant effect of master's thesis in his meta-analysis, we can also expect an effect of this publication type. In our case, we suspect that Master students have less incentive to find an EKC, *ceteris paribus*. We also include the presence of control variables for inequalities, life expectancy[4] and

[4] Life expectancy is correlated with environmental quality (Mariani et al. 2010).

infrastructures. We expect the inclusion of these variables to alter the income-deforestation relationship. In fact, they are correlated with income and this may rise collinearity issues or shed light on transmission channels. Finally we add other sources of variation namely the sample size, the h-index of the publication,[5,6] the type of model estimated (quadratic or cubic) and the number of regressions presented.[7,8]

**Table 1. Description and descriptive statistics of variables**

| Variables | Description | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| EKC | = 1 if an EKC is found, 0 otherwise | 0.330 | 0.470 | | |
| Year | Publication year | 2004.582 | 4.705 | 1992 | 2011 |
| initial data | Initial year of data | 1978.182 | 12.908 | 1948 | 2006 |
| end data | Final year of data | 1997.403 | 5.475 | 1984 | 2010 |
| sample size | Sample size | 73.643 | 211.526 | 4 | 2619 |
| H index | H index of the publication | 0.518 | 0.412 | 0.000286 | 1.000286 |
| reg | Number of regressions presented in the study | 24.324 | 19.81 | 1 | 60 |
| Measures of deforestation | | | | | |
| deforestation1 | = 1 if Agricultural land expansion rate, 0 otherwise | 0.019 | 0.137 | | |
| deforestation2 | = 1 if Arable land area, 0 otherwise | 0.016 | 0.125 | | |
| deforestation3 | = 1 if Built-up land, 0 otherwise | 0.005 | 0.069 | | |
| deforestation4 | = 1 if Crop Area, 0 otherwise | 0.040 | 0.195 | | |
| deforestation5 | = 1 if Deforestation, 0 otherwise | 0.777 | 0.417 | | |
| deforestation6 | = 1 if Forest area clearcut, 0 otherwise | 0.013 | 0.112 | | |
| deforestation7 | = 1 if Forest stock, 0 otherwise | 0.071 | 0.258 | | |
| deforestation8 | = 1 if Land use for fuel wood, charcoal, paper, and pulp, 0 otherwise | 0.005 | 0.069 | | |
| deforestation9 | = 1 if Land use for pasture, 0 otherwise | 0.005 | 0.069 | | |
| deforestation10 | = 1 if Land use to produce timber, 0 otherwise | 0.005 | 0.069 | | |
| deforestation11 | = 1 if Mangrove deforestation index, 0 otherwise | 0.006 | 0.079 | | |
| deforestation12 | = 1 if Paved roads in forest regions, 0 otherwise | 0.029 | 0.167 | | |
| deforestation13 | = 1 if Roads encroaching on forest cover, 0 otherwise | 0.006 | 0.079 | | |

[5] The lower, the better

[6] This ranking is done by "Ideas Repec". At the date of last visit, journals were ranked from 1 to 3 496. So we calculated a ratio that is equal to the rank of the journal divided by the rank of the last journal listed (i.e. 3 496). However for studies that did not receive a ranking on this site, the ratio calculation was made assuming that the rank of this study will be equal to the rank of the last journal classified to which was added one.

[7] Note that few studies provide tests to compare models. It is therefore not possible to provide a single regression per article.

[8] Other information was collected from studies but was excluded due to collinearity issues such as the unit for the deforestation measure, the source of data for deforestation, etc.

| Variables | Description | Mean | SD |
|---|---|---|---|
| deforestation14 | = 1 if Timber harvest rate, 0 otherwise | 0.002 | 0.040 |
| deforestation15 | = 1 if Urban forest canopy percentage, 0 otherwise | 0.003 | 0.056 |
| Econometric techniques | | | |
| econometrics1 | = 1 if Dynamic Panel, 0 otherwise | 0.016 | 0.125 |
| econometrics2 | = 1 if Geographically Weighted Regression, 0 otherwise | 0.003 | 0.056 |
| econometrics3 | = 1 if Least Absolute Deviation, 0 otherwise | 0.002 | 0.040 |
| econometrics4 | = 1 if Logistic Panel Smooth Transition Regression, 0 otherwise | 0.016 | 0.125 |
| econometrics5 | = 1 if Monte Carlo Estimation, 0 otherwise | 0.006 | 0.079 |
| econometrics6 | = 1 if Ordinary Least Squares, 0 otherwise | 0.434 | 0.496 |
| econometrics7 | = 1 if Panel Fixed Effects, 0 otherwise | 0.387 | 0.487 |
| econometrics8 | = 1 if Panel Random Coefficients, 0 otherwise | 0.013 | 0.112 |
| econometrics9 | = 1 if Panel Random Effects, 0 otherwise | 0.082 | 0.275 |
| econometrics10 | = 1 if Spatial Panel Fixed Effects, 0 otherwise | 0.019 | 0.137 |
| econometrics11 | = 1 if Spatial Panel Random Effects, 0 otherwise | 0.013 | 0.112 |
| econometrics12 | = 1 if Time Series, 0 otherwise | 0.010 | 0.097 |
| fe_retain | = 1 if Panel Fixed Effects chosen with Hausman test, 0 otherwise | 0.371 | 0.483 |
| re_retain | = 1 if Panel Random Effects chosen with Hausman test, 0 otherwise | 0.043 | 0.203 |
| Geographical areas | | | |
| area1 | = 1 if Africa, 0 otherwise | 0.043 | 0.203 |
| area2 | = 1 if Africa and Asia, 0 otherwise | 0.014 | 0.119 |
| area3 | = 1 if Africa, Asia, North America, Latin America and Oceania, 0 otherwise | 0.019 | 0.137 |
| area4 | = 1 if Africa, Asia, North America and Oceania, 0 otherwise | 0.006 | 0.079 |
| area5 | = 1 if Africa, Asia and Latin America, 0 otherwise | 0.301 | 0.459 |
| area6 | = 1 if Africa, Asia, Latin America and Europe, 0 otherwise | 0.008 | 0.089 |
| area7 | = 1 if Africa, Asia, Latin America and Oceania, 0 otherwise | 0.006 | 0.079 |
| area8 | = 1 if Asia, 0 otherwise | 0.086 | 0.280 |
| area9 | = 1 if Asia and Latin America, 0 otherwise | 0.070 | 0.255 |
| area10 | = 1 if Europe, 0 otherwise | 0.024 | 0.152 |
| area11 | = 1 if Latin America, 0 otherwise | 0.073 | 0.260 |
| area12 | = 1 if North America, 0 otherwise | 0.022 | 0.147 |
| area13 | = 1 if World, 0 otherwise | 0.328 | 0.470 |
| Economic development measures | | | |
| development1 | = 1 if GDP, 0 otherwise | 0.642 | 0.480 |
| development2 | = 1 if GNP, 0 otherwise | 0.068 | 0.252 |
| development3 | = 1 if Household median income, 0 otherwise | 0.003 | 0.056 |
| development4 | = 1 if Human Development Index, 0 otherwise | 0.165 | 0.371 |
| development5 | = 1 if Per capita consumption, 0 otherwise | 0.011 | 0.105 |
| development6 | = 1 if Poverty, 0 otherwise | 0.010 | 0.097 |
| development7 | = 1 if Urbanization, 0 otherwise | 0.101 | 0.302 |
| Publication types | | | |
| pub type1 | = 1 if Article, 0 otherwise | 0.498 | 0.500 |
| pub type2 | = 1 if Conference Paper, 0 otherwise | 0.024 | 0.152 |
| pub type3 | = 1 if Discussion Paper, 0 otherwise | 0.013 | 0.112 |
| pub type4 | = 1 if Other, 0 otherwise | 0.166 | 0.373 |

| | | | |
|---|---|---|---|
| pub type5 | = 1 if Working Papers, 0 otherwise | 0.300 | 0.458 |
| Presence of control variables | | | |
| life expectancy | = 1 if life expectancy variable, 0 otherwise | 0.002 | 0.040 |
| inequality | = 1 if inequality variable, 0 otherwise | 0.024 | 0.152 |
| infrastructures | = 1 if infrastructures variable, 0 otherwise | 0.063 | 0.244 |
| Others | | | |
| cubic | = 1 if Cubic model, 0 otherwise | .0443 | 0.206 |
| quadratic | = 1 if Quadratic model, 0 otherwise | 0.956 | 0.206 |

N = 631

## 5. Empirical Strategy and Results

Our response variable is a binary variable "EKC".[9] Recall that we investigate the factors that influence the occurrence of an EKC.[10] We first estimate the model using robust ordinary least squares.[11] Indeed, in the presence of a binary dependent variable, if the model is estimated by OLS, the errors are heteroskedastic. Therefore, it is appropriate to make a robust estimation with White-corrected standard errors. Furthermore, given that there may be a within-study autocorrelation leading to the dependence of regressions within one article, we ran OLS with cluster-robust inference.[12] The reason is that each study estimates various regressions with different units of measures (cf. Table 2). Then, we perform a bootstrap to deal with non-normality of residuals and to get reliable standard errors.

[9] In the field of environmental economics, the use of a binary criterion into a meta-analysis was used, among others, by (Jeppesen et al. 2002; Schläpfer 2006; Jacobsen & Hanley 2008; Kiel & Williams 2007; Jordan 2010)

[10] It is important to note that, in this paper, we do not look into "effects size" which would imply using the income associated with turning points.

[11] Several authors recommend running OLS when a binary variable is the endogenous regressor. See (Angrist 2001) for more details.

[12] Standard errors are clustered by each study. Such approach has been used, for instance, by (Barrio & Loureiro 2010).

**Table 2. Robust OLS equations**

| VARIABLES | OLS robust | OLS cluster-robust | Boostrap OLS cluster-robust |
|---|---|---|---|
| year | -0.0220** | -0.0220 | -0.0220*** |
| | (0.00997) | (0.0160) | (0.00812) |
| initial data | 0.00591** | 0.00591 | 0.00591*** |
| | (0.00276) | (0.00495) | (0.00218) |
| end data | 0.0111 | 0.0111 | 0.0111 |
| | (0.00947) | (0.0151) | (0.00763) |
| sample size | 0.000474*** | 0.000474*** | 0.000474*** |
| | (6.13e-05) | (9.72e-05) | (4.70e-05) |
| H index | -0.0686 | -0.0686 | -0.0686 |
| | (0.0799) | (0.170) | (0.0495) |
| deforestation2 | 0.483 | 0.483* | 0.483* |
| | (0.295) | (0.272) | (0.249) |
| deforestation3 | -0.468*** | -0.468** | -0.468*** |
| | (0.130) | (0.184) | (0.117) |
| deforestation5 | -0.0203 | -0.0203 | -0.0203 |
| | (0.111) | (0.158) | (0.0909) |
| deforestation6 | -0.364** | -0.364* | -0.364*** |
| | (0.149) | (0.211) | (0.123) |
| deforestation7 | -0.188 | -0.188 | -0.188 |
| | (0.154) | (0.246) | (0.123) |
| deforestation8 | -0.468*** | -0.468** | -0.468*** |
| | (0.130) | (0.184) | (0.119) |
| deforestation9 | -0.135 | -0.135 | -0.135 |
| | (0.293) | (0.184) | (0.334) |
| deforestation10 | -0.135 | -0.135 | -0.135 |
| | (0.293) | (0.184) | (0.340) |
| deforestation11 | 0.559*** | 0.559** | 0.559*** |
| | (0.175) | (0.252) | (0.146) |
| deforestation12 | -0.0653 | -0.0653 | -0.0653 |
| | (0.162) | (0.184) | (0.146) |
| deforestation13 | -0.410*** | -0.410* | -0.410*** |
| | (0.143) | (0.223) | (0.127) |
| deforestation14 | 0.477*** | 0.477* | 0.477*** |
| | (0.162) | (0.269) | (0.126) |
| econometrics1 | 0.140 | 0.140 | 0.140 |
| | (0.159) | (0.180) | (0.162) |
| econometrics2 | -0.684*** | -0.684*** | -0.684*** |
| | (0.165) | (0.204) | (0.147) |
| econometrics3 | 0.623*** | 0.623** | 0.623*** |
| | (0.137) | (0.255) | (0.109) |
| econometrics6 | -0.0403 | -0.0403 | -0.0403 |
| | (0.0795) | (0.0984) | (0.0732) |
| fe_retain | 0.0940 | 0.0940 | 0.0940 |
| | (0.0814) | (0.0868) | (0.0739) |
| econometrics8 | -0.435*** | -0.435*** | -0.435*** |
| | (0.113) | (0.143) | (0.114) |
| re_retain | -0.103 | -0.103 | -0.103 |
| | (0.126) | (0.144) | (0.114) |
| econometrics10 | -0.406*** | -0.406*** | -0.406*** |
| | (0.0920) | (0.121) | (0.0853) |
| econometrics11 | -0.406*** | -0.406*** | -0.406*** |
| | (0.0932) | (0.121) | (0.0868) |
| econometrics12 | 0.181 | 0.181 | 0.181 |
| | (0.257) | (0.307) | (0.182) |
| area1 | 0.0487 | 0.0487 | 0.0487 |
| | (0.0949) | (0.146) | (0.0859) |
| area2 | -0.273** | -0.273 | -0.273** |
| | (0.122) | (0.236) | (0.124) |
| area3 | -0.590*** | -0.590*** | -0.590*** |
| | (0.0724) | (0.112) | (0.0670) |
| area4 | -0.588*** | -0.588*** | -0.588*** |
| | (0.0723) | (0.112) | (0.0669) |
| area5 | 0.103* | 0.103 | 0.103** |
| | (0.0570) | (0.122) | (0.0454) |
| area6 | -0.00590 | -0.00590 | -0.00590 |
| | (0.240) | (0.114) | (0.253) |
| area8 | -0.0388 | -0.0388 | -0.0388 |
| | (0.0833) | (0.136) | (0.0694) |
| area10 | 0.0532 | 0.0532 | 0.0532 |

| | | | |
|---|---|---|---|
| | (0.151) | (0.159) | (0.142) |
| area11 | 0.135 | 0.135 | 0.135 |
| | (0.0962) | (0.191) | (0.0867) |
| area12 | -0.117* | -0.117 | -0.117** |
| | (0.0638) | (0.0877) | (0.0592) |
| development1 | 0.140** | 0.140 | 0.140*** |
| | (0.0656) | (0.131) | (0.0498) |
| development3 | 0.661*** | 0.661*** | 0.661*** |
| | (0.140) | (0.200) | (0.118) |
| development5 | 0.302* | 0.302 | 0.302* |
| | (0.176) | (0.186) | (0.182) |
| pub type1 | 0.0232 | 0.0232 | 0.0232 |
| | (0.0733) | (0.138) | (0.0528) |
| pub type2 | -0.234 | -0.234 | -0.234 |
| | (0.220) | (0.244) | (0.163) |
| pub type3 | -0.250** | -0.250 | -0.250*** |
| | (0.124) | (0.191) | (0.0946) |
| pub type4 | -0.240** | -0.240 | -0.240*** |
| | (0.107) | (0.184) | (0.0821) |
| life expectancy | -0.195* | -0.195* | -0.195** |
| | (0.109) | (0.114) | (0.0978) |
| Inequality | 0.504*** | 0.504** | 0.504*** |
| | (0.150) | (0.201) | (0.0876) |
| Infrastructures | -0.352*** | -0.352** | -0.352*** |
| | (0.106) | (0.170) | (0.0781) |
| quadratic | 0.251** | 0.251** | 0.251*** |
| | (0.106) | (0.107) | (0.0868) |
| reg | 0.000892 | 0.000892 | 0.000892 |
| | (0.00198) | (0.00287) | (0.00165) |
| Constant | 10.35 | 10.35 | 10.35 |
| | (11.22) | (25.74) | (8.122) |
| Observations | 631 | 631 | 631 |
| R-squared | 0.242 | 0.242 | 0.242 |

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Due to the high number of variables available – some being redundant – in a meta-analysis, multicollinearity is a serious concern. Recall that multicollinearity leads to unstable coefficients and inflated standard errors. We use Variance Inflation Factors (VIFs) to detect it (cf. Table 3). Different views exist on the threshold to accept. Some argue that VIFs should not go beyond 30; others adopt a more strict value of 10. As shown in Table 3, VIF values do not exceed 10. What is more, the mean of VIFs is not considerably larger than 1, which goes in line with the most conservative rule of thumb (Chatterjee & Hadi 2006). We then perform the Ramsey's RESET test, on robust OLS, in order to check for omitted variables and model misspecification.[13]

[13] We find that F(3, 578) = 1.23 with Prob > F = 0.2981. Therefore there is no omitted variable / misspecification issue in the model.

**Table 3. Variance Inflation Factors**

| Variables | VIF | | | | |
|---|---|---|---|---|---|
| end data | 7.28 | infrastructures | 2.12 | econometrics11 | 1.33 |
| econometrics6 | 6.37 | re_retain | 2.12 | econometrics2 | 1.29 |
| fe_retain | 5.96 | deforestation12 | 2.02 | deforestation13 | 1.28 |
| year | 5.88 | area5 | 2 | area3 | 1.26 |
| deforestation5 | 5.42 | pub type3 | 1.7 | deforestation10 | 1.2 |
| pub type4 | 4.53 | development3 | 1.66 | deforestation3 | 1.2 |
| deforestation7 | 4.45 | area11 | 1.65 | deforestation8 | 1.2 |
| deforestation2 | 4.04 | econometrics1 | 1.57 | deforestation9 | 1.2 |
| reg | 3.75 | econometrics12 | 1.56 | development5 | 1.13 |
| area12 | 3.67 | inequality | 1.54 | area6 | 1.11 |
| deforestation6 | 3.66 | sample size | 1.54 | deforestation14 | 1.1 |
| pub type2 | 3.59 | deforestation11 | 1.5 | area2 | 1.09 |
| pub type1 | 3.57 | area10 | 1.5 | area4 | 1.09 |
| initial data | 3.51 | econometrics10 | 1.49 | econometrics3 | 1.08 |
| H index | 3.06 | econometrics8 | 1.46 | life expectancy | 1.08 |
| development1 | 2.79 | area1 | 1.39 | | |
| area8 | 2.26 | quadratic | 1.38 | **Mean VIF** | **2.44** |

Secondly, we estimate a Logit model and a Probit model with robust standard deviations. The choice of one distribution or the other does not induce significant differences between the results, although tests slightly favour the Probit model.[14] Table 4 presents marginal effects for the Probit model.[15]

[14] Tests and Logit estimations are available upon request. See Table A - 2 in the Appendix.

[15] Logit and Probit estimations are available upon request to authors. Logit and Probit estimations are run on 546 observations (compared with 613 for OLS) because we have few observations for some variables.

**Table 4. Probit marginal effects**

| VARIABLES | Robust probit | Probit cluster-robust | Probit Bootstrap cluster-robust |
|---|---|---|---|
| Year | -0.0269** | -0.0269 | -0.0269*** |
| | (0.0112) | (0.0176) | (0.0102) |
| initial data | 0.00829*** | 0.00829 | 0.00829*** |
| | (0.00316) | (0.00531) | (0.00274) |
| end data | 0.0110 | 0.0110 | 0.0110 |
| | (0.0104) | (0.0164) | (0.00879) |
| sample size | 0.00209** | 0.00209 | 0.00209*** |
| | (0.000812) | (0.00173) | (0.000711) |
| H index | -0.0889 | -0.0889 | -0.0889 |
| | (0.0843) | (0.180) | (0.0573) |
| deforestation2 | 0.486** | 0.486** | 0.486 |
| | (0.218) | (0.200) | (0.507) |
| deforestation5 | -0.0805 | -0.0805 | -0.0805 |
| | (0.126) | (0.164) | (0.114) |
| deforestation7 | -0.216* | -0.216 | -0.216** |
| | (0.116) | (0.181) | (0.105) |
| deforestation9 | -0.210 | -0.210 | -0.210 |
| | (0.196) | (0.152) | (0.137) |
| deforestation10 | -0.210 | -0.210 | -0.210* |
| | (0.196) | (0.152) | (0.127) |
| deforestation12 | 0.0263 | 0.0263 | 0.0263 |
| | (0.174) | (0.233) | (0.155) |
| econometrics1 | 0.183 | 0.183 | 0.183 |
| | (0.232) | (0.277) | (0.181) |
| econometrics6 | -0.0771 | -0.0771 | -0.0771 |
| | (0.110) | (0.140) | (0.108) |
| fe_retain | 0.105 | 0.105 | 0.105 |
| | (0.108) | (0.122) | (0.114) |
| re_retain | -0.134 | -0.134 | -0.134 |
| | (0.135) | (0.151) | (0.150) |
| econometrics12 | 0.220 | 0.220 | 0.220 |
| | (0.279) | (0.336) | (0.201) |
| area1 | 0.133 | 0.133 | 0.133 |
| | (0.143) | (0.177) | (0.150) |
| area2 | -0.264** | -0.264 | -0.264*** |
| | (0.111) | (0.167) | (0.0793) |
| area5 | 0.166** | 0.166 | 0.166*** |
| | (0.0678) | (0.124) | (0.0523) |
| area6 | 0.0312 | 0.0312 | 0.0312 |
| | (0.233) | (0.104) | (0.209) |
| area8 | 0.0259 | 0.0259 | 0.0259 |
| | (0.136) | (0.178) | (0.118) |
| area10 | 0.156 | 0.156 | 0.156 |
| | (0.175) | (0.207) | (0.191) |
| area11 | 0.292** | 0.292* | 0.292** |
| | (0.124) | (0.176) | (0.118) |
| development1 | 0.123* | 0.123 | 0.123** |
| | (0.0679) | (0.133) | (0.0573) |
| development5 | 0.418** | 0.418** | 0.418*** |
| | (0.168) | (0.172) | (0.159) |
| pub type1 | 0.0107 | 0.0107 | 0.0107 |
| | (0.0754) | (0.134) | (0.0588) |
| pub type2 | -0.221 | -0.221 | -0.221 |
| | (0.177) | (0.194) | (0.499) |
| pub type4 | -0.251*** | -0.251 | -0.251*** |
| | (0.0901) | (0.153) | (0.0802) |
| inequality | 0.530*** | 0.530*** | 0.530*** |
| | (0.0950) | (0.133) | (0.0605) |
| infrastructures | -0.297*** | -0.297*** | -0.297*** |
| | (0.0636) | (0.106) | (0.0514) |
| quadratic | 0.245*** | 0.245*** | 0.245*** |
| | (0.0764) | (0.0827) | (0.0798) |
| reg | 0.000182 | 0.000182 | 0.000182 |
| | (0.00202) | (0.00275) | (0.00189) |
| Constant | | | |
| Observations | 546 | 546 | 546 |
| Pseudo $R^2$ | 0.1478 | 0.1478 | 0.1478 |

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The quality of fit is tested. The quality of the prediction in contingency tables is reported Table 5. The threshold is fixed at 36 % because in the population (546 observations), there are 36 % of "EKC" and 64 % of "no EKC". Results suggest that we reach 66.85 % of good predictions with the Probit model.

**Table 5. Contingency tables**

| **Probit model for EKC** | | | |
|---|---|---|---|
| Classified | D | -D | Total |
| + | 156 | 137 | 293 |
| - | 44 | 209 | 253 |
| Total | 200 | 346 | 546 |
| Correctly classified : 66.85% | | | |

Classified + if predicted Pr(D) >= .36; True D defined as EKC = 0.

To validate the robustness of our results, we use other thresholds to reject the EKC, that is to say 1% and 5% instead of 10% retained in this work. In other words, we build two new dependent variables EKC01 and EKC05. With the first one, we choose a significance level of 1% for the variables GDP per capita and its square. With the second we use a threshold of 5%. Using the 10 % threshold we have 32 % of the observations validating the EKC. It falls to 27 % for the 5 % threshold and 17 % for the 1 % one. We then estimate the Probit model. Results do not significantly change.[16]

# 6. Results and Discussion

## 6.1. Main results

Our results show that the most recent year of publication is (*year*), the more likely to have an EKC declines. We shall then identify the existence of non-linearity with respect to the year of publication. In the OLS regressions (robust, cluster and bootstrap cluster), we add the square of the year of publication. Both variables *year* and its square appear to be significant in the three models, the first one having a positive coefficient and the second having a negative one. In addition, coefficients are the same in each model

[16] Tables are available from the authors upon request (See Table A – 3 in the Appendix)

(respectively 18.89 and 0.00472). The turning point is around the year 2001.[17,18] This may be attributable to several factors, including an academic fad and technology (econometric practices and better availability of data).

Empirical choices should be carefully done before deriving policies from empirical results. On this issue, our results are not clear-cut which is not in line with (D. I. Stern 2004) contention according to which early empirical evidences of EKCs where the result of weak econometrics.[19] It is clear however from OLS regressions that the integration of a spatial dimension (*econometrics10 econometrics11*) decreases the likelihood of an EKC.[20] Although these results are not to be taken *per se*, they raise the question of the existence of spillovers between the rates of deforestation of countries. If these spillovers exist, does it change the nature of the relationship between economic development and deforestation? Existing work seem to go in that direction (e.g. Nguyen Van & Azomahou 2007).

We therefore believe that future work should incorporate the spatial dimension in order to control for the existence of spatial autocorrelation (Anselin 1988). Regarding deforestation, there may be several sources of spatial dependence between countries. First, national policies for forest conservation may be influenced by policies in neighboring countries resulting in a pattern of political spatial dependence. Second, there may be positive or negative ecological spillovers between countries. For instance,

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[17] 18.89/(2*0.00472) = 2001.06

[18] Our robustness check provides consistent turning points. We precisely find 1999.29 for 1 %, 2000.98 for 5 % and 2000.39 for 10 %.

[19] The existence of an EKC for deforestation was seldom performed on time series data. It was however the case with other types of pollutants such like $CO_2$ or $SO_2$. Even with recent econometric techniques, the results on the existence of an EKC are not conclusive (see e.g. Bernard et al. 2011).

[20] It is likely that the number of spatial regressions is too small to be captured in Logit and Probit estimations. We run a regression with three dummies for econometric techniques: OLS, panel (dynamic, fixed effects and random effects) and spatial (panel and GWR). It did not change the results. OLS and panel estimations were not significant, whereas spatial estimations were negative and significant.

seeds or forest fires – if necessary to recall – do not respect political boundaries. Third, unobserved variables may be related by a spatial process. In the case of deforestation, these may be climatic or geomorphological variables. And fourth, phenomena in neighboring countries are likely to influence deforestation patterns in a given country. For example, more stringent forest protection policies in a country may cause more deforestation in an adjacent country. As a matter of fact, there is uncertainty about the choice of the relevant spatial model (i.e. whether to estimate a spatial lag model, a spatial error model, a spatial Durbin model or a Cliff-Ord type model). All effects can occur simultaneously and there is no theoretical argument to exclude a form of spatial dependence a priori. The use of spatial econometrics is relatively recent. Theoretical (Corrado & Fingleton 2011; Elhorst 2010) and technical literature is growing fast (Drukker et al. 2011). Regarding the EKC for deforestation thanks to the better availability of data, their use will be facilitated and more relevant. This is an avenue of research to dig that could call into question the existence of an EKC for deforestation.

At that point, we cannot conclude on the quality of data although this concern was put forward (D. I. Stern et al. 1996).[21] Still, we do find that the more recent data coincide with the more chance of getting an EKC. It therefore stems the following question: Is it appropriate to mix data of different quality? Our analysis cannot answer that question.

## 6.2. Five remarks

Sample size

The sample size (*sample size*) has a positive and significant effect on the existence of the EKC. This result is line with other meta-analyses (Jeppesen et al. 2002). Indeed,

[21] When gathering information we have extracted the data source. However, this information could not be used in the meta-analysis because these variables are highly correlated with measures of deforestation and because their source very often relies on FAO data.

according to standard testing theory sample sizes increase the power of tests. In other words, larger sample sizes reduce the probability of erroneously accepting the null hypothesis.

Deforestation index

The term “deforestation” is not clear-cut. It covers a wide range of meanings. This is striking in EKC studies for deforestation. Authors use different measures (Table 1). Our results do not evidence a clear effect of the deforestation index on the probability of the occurrence of an EKC for deforestation.

Infrastructures

Deforestation is driven by numerous factors. In some studies, authors only focus on the income-deforestation nexus. In others, authors add control variables. We find that adding infrastructures variables (*infrastructures*) decreases the probability of obtaining an EKC. There is evidence that infrastructure expansion is a cause of deforestation (Pfaff 1999). However, this variable may be highly correlated to income. (D. I. Stern 2004) addresses this issue and concludes that it is difficult to infer from studies that include additional control variables. We add that our results for infrastructures are not surprising. Indeed, if they are correlated with per capita income, it is normal that authors do not find a significant relationship between economic development and deforestation. Yet, we argue that it is not enough to conclude that there is no EKC in that specific case, because such result could also be explained by the fact that this variable plays a role in channelling the effect of economic development on deforestation.

Inequality index

We find a strong positive relationship between the introduction of a control variable for inequalities (*inequality*) and the probability of finding an EKC. Our result does not contradict (Koop & Tole 2001) and (Heerink et al. 2001). They find that high inequality strengthens the effect of economic development on deforestation.

Publication type

If the type of publication is a Master's thesis (*pub type4*), then the probability of an EKC declines relative to an article, a working paper or conference paper, *ceteris paribus*. This could be explained by a "publication strategy" effect. A Master's student seems not to have the same incentives to validate the existence of an EKC whereas a researcher may be more prone to evidence an EKC as a means to publish his work in an academic journal.

### 6.3. Publication Bias

Publication bias remains today the biggest problem facing meta-analyses. Indeed in principle, the meta-analysis must combine exhaustively all the studies that have been made in the area of interest. First there may be a bias in the reporting of results: the estimation results are more likely to be published if they are significant. This problem is referred as the "file drawer" problem by meta-analysts (Stanley et al. 2008). Non-significant results may not be submitted to academic journals (nor published as a working paper) or they may be more rejected by publishers of academic journals. Thus the literature is not a perfect representation of all work in the field. The sources of this type of bias are complex and highly dependent on the decisions of the authors as well as publishers. Secondly, studies with "good results" are often published in English. Here, the means of dissemination may also be a source of publication bias.

Also, in our analysis we do not take into account the quality of the papers. This problem is referred to as "garbage in, garbage out" (Borenstein et al. 2009). However, we believe that excluding articles, on its own, would only add bias, compared to what we believe to be a "good paper". In addition, our work allows rather performing "waste management".[22] In this sense, our work examines the characteristics of the studies that are related to the occurrence of results.

## 7. Concluding Remarks

The objective of this paper was to shed light on why EKC for deforestation results differ across studies. And that, in view of raising the attention of researchers, practitioners and policy makers on the underlying causes that lead to the validation of the EKC for deforestation in the academic literature, despite critical reviews of EKCs. We have therefore constructed an original database gathering the characteristics of econometric results for EKCs for deforestation and then implemented a meta-analysis.

Our main results are the following. Recent estimates do not corroborate the EKCs for deforestation. The year 2001 appears to be a turning point. Our results also confirm that empirical choices i.e. estimators choice affect the occurrence of an EKC for deforestation with respect to the hypothesis of spatial autocorrelation in deforestation rates. The contention of (D. I. Stern 2004) of the poor quality of econometrics underlying EKCs estimates is thus given a particular flavour.

[22] In the metaphorical sense proposed by (Borenstein et al. 2009)

Finally, let us consider another interpretation of our results in a Popperian way. A reason why EKCs are still considered is that scholars hardly make a definitive refutation of the EKC hypothesis; they rather prefer evidencing the presence or the absence of corrobation. Indeed, in order to test the relevance of the theory underlying the EKC, scholars must consider auxiliary hypotheses. In the case of the EKC those auxiliary hypotheses are partly provided by the econometric hypotheses. When the EKC is not corroborated, scholars cannot identify whether it is the result of falsified theory or of the econometric hypotheses. This is the essence of Quine's holism (Quine 1951): the EKC for deforestation cannot be tested in isolation.[23] The EKC story is not at its end. Building on our results, we can predict that empirical and theoretical research on EKCs is still lively until theoretical alternatives will be provided. Following Popper, we can hope that "refuted theory can be repaired to cope with the newly discovered anomalies" (Blaug 1992, p.25)

Lastly, as mentioned earlier, a meta-analysis opens the way for prospective meta-analysis. In future work, we shall explore the quality of estimations. Indeed, in this article we focused on estimators. Notably, we shall focus on EKC studies using panel techniques and investigate the study-to-study variation focusing on econometric tests performed such as tests for endogeneity, multicollinearity, Hausman test, etc.

[23] The critic of Quine is also referred as the Duhem-Quine critic on the confirmation holism.

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# Appendix A – For the referees, not for publication

**Table A – 1. Studies included in the sample (authors, year of publication, support of the publication)**

Antle & Heidebrink (1995) *Economic Development and Cultural Change*
Araujo et al (2009) *Ecological Economics*
Arcand et al (2008) *Journal of Development Economics*
Arcand et al (2002) *CERDI working papers*
Barbeau (2003) *University de Montreal, Départment de sciences économiques, Rapport de recherche*
Barbier (2004) *American Journal of Agricultural Economics*
Barbier & Burgess (2001) *Journal of Economic Surveys*
Basu & Nayak (2011) *Forest Policy and Economics*
Bhattarai & Hammig (2004) *Environment and Development Economics*
Bhattarai & Hammig (2001) *World Development*
Castro Gomes & José Braga (2008) *Universidade Federal De Viçosa-UFV, Working papers*
Buitenzorgy & Mol (2011) *Environmental and Resource Economics*
Caviglia-Harris et al (2009) *Ecological Economics*
Combes et al (2008) *CERDI working papers*
Combes et al (2010) *CERDI working papers*
Combes Motel et al (2009) *Ecological Economics*
Corderi (2008) *Economic Analysis Working Papers, Colexio de Economistas de A Coruña, Spain and Fundación Una Galicia Moderna*
Cornelis van Kooten & Wang (2003) *XII World Forestry Congress (FAO)*
Corrêa de Oliveira & Simoes de Almeida (2011) *Department of Economics- Federal University of Juiz Juiz de Fora*
Cropper & Griffiths (1994) *American Economic Review*
Culas & Dutta (2003) *Working papers, University of Sydney, Department of economics*
Culas (2007) *Ecological Economics*
Damette & Delacote (2011) *Ecological Economics*
Delacote (2003) *Mémoire de DEA CERDI*
Diarra & Marchand (2011) *CERDI working papers*
Diarrasouba & Boubacar (2009) *Selected paper for presentation at the southern Agricultural economics Association Annual Meeting*
Duval & Wolff (2009) *Laboratoire d'Economie et de Management Nantes-Atlantique Université de Nantes, HAL working Papers*
Ehrhardt-Martinez et al (2002) *Social Science Quarterly*
Ehrhardt-Martinez (1998) *Social Forces*
Ferreira (2004) *Land Economics*
Frankel & Rose (2002) *NBER Working papers*
Galinato & Galinato (2010) *Working papers, School of Economic Sciences, Washington State University*
Gangadharan & Valenzuela (2001) *Ecological Economics*
Heerink et al (2001) *Ecological Economics*
Hilali & Ben Zina (2007) *Unité de Recherches sur la Dynamique Economique et l'Environnement (URDEE)*
Hyde et al (2008) *Environment for Development*
Jorgenson (2006) *Rural Sociology*
Jorgenson (2008) *The Sociological Quarterly*
Kahuthu (2006) *Environment, Development and Sustainability*
Kallbekken (2000) *Environmental Economics and Environmental Management, University of York*
Kishor & Belle (2004) *Journal of Sustainable Forestry*
Koop & Tole (1999) *Journal of Development Economics*
Lantz (2002) *Journal of Forest Economics*
Lee et al (2009) *Singapore Economic review conference*
Leplay & Thoyer (2011) *Laboratoire d'Economie et de Management Nantes-Atlantique Université de Nantes, HAL working Papers*
Li (2006) *International Studies Quarterly*
Lim (1997) *School of economics, University of New South Wales Sydney, NSW 2no52, Australia*
Lopez & Galinato (2004) *Environmental Protection Agency (EPA) report*
Marchand (2010) *CERDI working papers*
Marquart-Pyatt (2004) *International Journal of Sociology*
Meyer et al (2003) *International Forestry Review*
Naito & Traesupap (2006) *Journal of The faculty of Economics, KGU*
Nguyen Van & Azomahou (2003) *Revue Economique*
Nguyen Van & Azomahou (2007) *Journal of Development Economics*
Panayotou (1993) *World Employment Programme research Working papers*
Perrings & Ansuategi (2000) *Journal of Economic Studies*
Reuveny et al (2010) *Journal of Peace Research*
Rock (1996) *Ecological Economics*
Shafik (1994) *Oxford Economic Papers*
Shafik & Bandyopadhyay (1992) *Policy Research Working papers, World Bank*
Shandra (2007) *Sociological Inquiry*
Shandra (2007) *International Journal of Comparative Sociology*
Shandra (2007) *Social Science Quarterly*
Skonhoft & Solem (2001) *Ecological Economics*
Turner et al (2006) *Scandinavian Journal of Forest Research*
Turner et al (2005) *Agricultural and Resource Economics Review*
Wang et al (2007) *Forest Policy and Economics*
Wang (2003) *XII World Forestry Congress 2nono3 (FAO)*
Yoshioka (2010) *Faculty of economics, Nagasaki University*
Zhao et al (2011) *Environment and Resource Economics*
Zhu & Zhang (2006) *Journal of Agricultural and Applied Economics*

**Table A – 2. Logit Marginal Effects**

| VARIABLES | Robust logit |
|---|---|
| Year | -0.0276** |
| | (0.0123) |
| initial data | 0.00818** |
| | (0.00339) |
| end data | 0.0113 |
| | (0.0110) |
| sample size_section | 0.00220** |
| | (0.000888) |
| H index | -0.0801 |
| | (0.0865) |
| deforestation2 | 0.491** |
| | (0.212) |
| deforestation5 | -0.0897 |
| | (0.137) |
| deforestation7 | -0.209* |
| | (0.113) |
| deforestation9 | -0.200 |
| | (0.179) |
| deforestation10 | -0.200 |
| | (0.179) |
| deforestation12 | 0.0257 |
| | (0.181) |
| econometrics1 | 0.178 |
| | (0.242) |
| econometrics6 | -0.0886 |
| | (0.116) |
| fe_retain | 0.0869 |
| | (0.114) |
| re_retain | -0.154 |
| | (0.134) |
| econometrics12 | 0.188 |
| | (0.308) |
| area1 | 0.151 |
| | (0.157) |
| area2 | -0.248** |
| | (0.117) |
| area5 | 0.178** |
| | (0.0720) |
| area6 | 0.0330 |
| | (0.233) |
| area8 | 0.0299 |
| | (0.148) |
| area10 | 0.173 |
| | (0.188) |
| area11 | 0.319** |
| | (0.134) |
| development1 | 0.124* |
| | (0.0705) |
| development5 | 0.432*** |
| | (0.151) |
| pub type1 | 0.00568 |
| | (0.0766) |
| pub type2 | -0.238 |
| | (0.163) |
| pub type4 | -0.271*** |
| | (0.0860) |
| inequality | 0.523*** |
| | (0.0954) |
| infrastructures | -0.279*** |
| | (0.0649) |
| quadratic | 0.237*** |
| | (0.0769) |
| reg | 0.000404 |
| | (0.00211) |
| Observations | 546 |
| Pseudo $R^2$ | 0.1472 |

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

**Table A - 3. Probit robustness check**

| VARIABLES | EKC01 | EKC05 |
|---|---|---|
| Year | -0.0936*** | -0.0630** |
| | (0.0361) | (0.0320) |
| initial data | 0.0378*** | 0.0195** |
| | (0.0118) | (0.00865) |
| end data | 0.0104 | 0.0111 |
| | (0.0382) | (0.0321) |
| sample size | 0.00556* | 0.00472** |
| | (0.00319) | (0.00211) |
| H index | -0.175 | -0.0494 |
| | (0.301) | (0.254) |
| deforestation2 | 4.822*** | 0.710 |
| | (0.736) | (0.934) |
| deforestation5 | -1.314*** | -0.886** |
| | (0.405) | (0.355) |
| deforestation7 | -2.194*** | -1.577*** |
| | (0.698) | (0.486) |
| deforestation9 | -1.019 | -0.933 |
| | (0.830) | (0.811) |
| deforestation10 | -1.019 | -0.933 |
| | (0.830) | (0.811) |
| deforestation11 | -1.009 | 0.686 |
| | (0.925) | (0.898) |
| deforestation12 | | -0.699 |
| | | (0.576) |
| econometrics1 | 0.249 | 0.483 |
| | (0.661) | (0.613) |
| econometrics6 | -0.559 | 0.0765 |
| | (0.402) | (0.322) |
| fe_retain | -0.125 | 0.278 |
| | (0.366) | (0.314) |
| re_retain | -0.798 | -0.497 |
| | (0.674) | (0.500) |
| econometrics12 | 1.743** | 1.101 |
| | (0.760) | (0.737) |
| area1 | 0.261 | 0.225 |
| | (0.486) | (0.375) |
| area2 | -0.894 | -0.916 |
| | (0.655) | (0.587) |
| area5 | 0.469** | 0.456*** |
| | (0.208) | (0.175) |
| area6 | | -0.385 |
| | | (0.606) |
| area8 | 0.168 | -0.151 |
| | (0.479) | (0.411) |
| area10 | | 0.0680 |
| | | (0.451) |
| area11 | -0.0783 | 0.565* |
| | (0.490) | (0.334) |
| development1 | 0.852*** | 0.389** |
| | (0.224) | (0.195) |
| development5 | 0.922 | 1.356** |
| | (0.683) | (0.605) |
| pub type1 | 0.269 | 0.0305 |
| | (0.269) | (0.215) |
| pub type2 | -4.576*** | -0.273 |
| | (0.355) | (0.768) |
| pub type4 | -1.598*** | -1.170*** |
| | (0.487) | (0.386) |
| inequality | 1.527*** | 0.789* |
| | (0.432) | (0.428) |
| infrastructures | -12.35 | -5.542*** |
| | (8.348) | (1.912) |
| quadratic | 0.771** | 0.828** |
| | (0.392) | (0.347) |
| reg | 0.0169** | 0.0101* |
| | (0.00686) | (0.00600) |
| Constant | 90.88** | 64.09** |
| | (36.65) | (31.70) |
| Observations | 512 | 550 |
| Pseudo $R^2$ | 0.2908 | 0.1873 |

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1