# Economic growth and biodiversity: Is there a peaceful cohabitation between natural and human habitats?

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**Abstract**

Some scientific views argue that economic activities might be expanding at the cost of biological species, while others advocate for a peaceful cohabitation. Hence, this paper proposes an analysis on the case of threatened animal and plant species, exploiting a panel dataset to test whether there is a peaceful cohabitation with human habitat. Our analysis indicates that the number of threatened species depicts an inverted U-shaped curve with income per capita and also shows that the more biological species-rich a region is, the more threatened species it holds. Compared to developing countries, developed countries definitely appear to be threatening fewer animal and plant species, suggesting a possible peaceful cohabitation. Relative species poverty, trade as well as production sectors (mostly secondary and tertiary) seem to be some of the forces behind the peaceful cohabitation observed in high-income countries. Overall, human population growth is harmful to animal and plant species.

*Keywords:* Biodiversity loss, threatened species, income, population, control function approach
***JEL Classification***: C23, C29, Q57.

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## 1. Introduction

Expansion of human habitat leads to biodiversity loss which in return threatens human well being. This perspective of impossible peaceful cohabitation is supported among others in ecological economics by researchers such as Tisdell (2003, 2011) and Diaz et al. (2006) and in environmental sociology by the treadmill of production theory (Schnaiberg, 1980; Schnaiberg et al., 2002). To find solutions to species loss, it becomes important to question the role of human habitat. On the topic, works among others by Grossman and Krueger (1995), John and Pecchenino (1997), Koop and Tole (1999), Nguyen-Van and Azomahou (2007), Brock and Taylor (2010) and Dasgupta (2010) contributed to the scholarship by working on issues such as gas emissions, deforestation but also biological species loss. In the same vein, this paper proposes to investigate the drivers of threatened species, globally testing the peaceful cohabitation hypothesis between human societies and animal and plant species.

Theoretical works on species loss as consequences of economic activities and population growth seem relatively few. Still, they permit an understanding of how economic expansion affects natural habitat. In this, Tisdell (2011) holds aggregate economic activity responsible for biodiversity loss while Lanz et al. (2018) point to intensive agriculture. Likewise, Cabo (1999), Polasky et al. (2002) and Alam and Quyen (2007) propose very comparable North-South models that highlight the role of international trade. Specifically, as introduced by Flam and Helpman (1987) and Copeland and Kotwal (1996), Alam and Quyen (2007) by assuming the South to be rich in forest land, outline how an unsustainable population growth in the South may have the same effects on biodiversity as trade openness.[1] Similar contributions to this literature led by Rosen et al. (1994), Farrow (1995), Carlos and Lewis (1999), and Taylor (2011) have been focused on the extinction of specific species.

Using economic models to explain species loss and ecosystem depletion actually traces back to the 1950s and even earlier. Gerhardsen (1952) and Scott (1954) followed by Schaefer (1957), Clark (1773, 1974) and Huang and Lee (1976), to cite a few, are some of the first authors to analyze fish and mammal species exploitation in economic frameworks. In a more recent literature, the question of resources depletion becomes whether nature will always be

[1] The main idea is having a comparative advantage in agricultural goods, trade openness may impel the South to clear forests in order to satisfy the demand for agricultural goods in both the South and the North.

able to support human societies, as the excessive demand and exploitation of natural resources cause environmental harms. This treadmill of production and neo-Malthusian perspectives are discussed by Smith (1975), Schnaiberg and Kenneth (1994), Brown (1995), Brander and Taylor (1998), among others. In this research perspective, ecosystem depletion and biodiversity loss threaten human societies and will lead to disastrous consequences.

The drivers of species extinction are empirically investigated by studies on the Environmental Kuznets Curve (EKC) hypothesis for threatened species.[2] Thereby, significant contributions are made by researchers such as Asafu-Adjaye (2003), Freytag et al. (2012), Carter et al. (2015) and Polaina et al. (2015) among others. Despite the Fuentes' (2011) argument for the absence of conflicts between economic growth and biodiversity, strong empirical results based on a wide range of biodiversity indicators suggest that human population dynamics, cities enlargement and economic expansion harm species diversity. Verboom et al. (2007) for instance project a decline of biodiversity in the near future while McDonald et al. (2008) underline the role of urbanization, as the latter severely shrinks distances to parks and leads to natural habitat destruction.

It is to mention that investigating an EKC for biodiversity loss is a very delicate exercise. Indeed, contrary to gas emissions where countries are supposed to be reducing their gas emissions after a certain level of income, biological diversity cannot be as easily reconstituted once species are extinct. Nevertheless, focusing on the threat to biodiversity such an investigation is feasible, since the indicators are stocks of endangered species. In so doing, Dietz and Adger (2003) and Mills and Waite (2009) using a species richness index, Hoffmann (2004) and McPherson and Nieswiadomy (2005) using a calculated endangering rate for mammal and bird species whereas Halkos and Tzeremes (2010) using a biodiversity performance measure, find results indicating that economic growth is not neutral in biodiversity loss. Relying solely on the count of threatened species classified into seven taxonomic groups, Kerr and Currie (1995), Naidoo and Adamowicz (2001), Majumder et al.(2006), Perrings and Halkos (2010), and Freytag et al. (2012), to cite few, provide results stating that economic growth harms

[2]The EKC hypothesis globally states that in the process of development, the environment depletion decreases after a certain level in GDP per capita, depicting an inverted U-shaped curve. Our focus being risks of biodiversity loss, we wish here to abstract from the large well known literature on EKC for the diverse environmental indicators and the challenges surrounding the existence of such a curve.

biodiversity by increasing the number of endangered species. It is noticeable that the previous empirical woks, with few exceptions, do not permit to claim the existence of an EKC for threatened species. Furthermore, plants being main biotic components of ecosystems, more attention should be given to the drivers of threatened plant species, in identifying how ecological impacts of human habitat can be reduced.

To the best of our knowledge, there are relatively few empirical research papers investigating the peaceful cohabitation assertion. Aiming to fill that gap, this paper contributes to the literature on the economic growth-biodiversity nexus for animal and plant species. To this end, we propose an empirical analysis on the link between human habitat and biological species loss, using as indicator of biodiversity loss the total counts of *critically endangered, endangered* and *vulnerable* animal and plant species. Two main arguments motivate our paper. First, focusing on threatened animal and plant species (mayor biotic factors) may help identify the main drivers of natural habitat loss, distinguishing high and low-income countries. Such a research focus helps explore whether there is a peaceful cohabitation between animal and plant species and economic expansion. Second, unlike the existing literature on deforestation, rather than being a plant population or forest cover analysis, considering threatened plant species precisely tackles a further aspect of the threat to biodiversity, which surprisingly has been less addressed in the existing literature.

Globally considering animal and plant species has the advantage of providing aggregate measures of the threat to the major biotic components of ecosystems.[3] Regarding our econometric model, it matches the nature of our data. We further control for endogeneity bias by relying on a control function to find results suggesting a possible harmonious cohabitation in high-income countries.[4] Separating high and low-income countries provides some hints about the mechanisms behind the observed patterns.

Section 2 presents the data and in Section 3 we discuss the income-threatened species nexus. Section 4 describes the econometric specification. Section 5 presents the results of our empirical analysis. In Sections 6 and 7, we discuss our results and draw some conclusions.

[3] This likely poses some data aggregating problems, as the real level of the threat in each taxonomic group (birds, amphibians, mammals) are unknown.

[4] The endogeneity bias will flaw the results if it is not appropriately tackled.

## 2. Data and descriptive statistics

### 2.1. The main series

*Indicators of biodiversity:* To investigate whether a peaceful cohabitation between natural and human habitats is possible, this paper exploits count of animal and plant species classified by the IUCN Red List as being threatened by extinction. More precisely, these are species qualified as vulnerable, endangered and critically endangered, since facing an extremely high risk of extinction.[5] Our indicators of the threat to animal and plant includes all taxonomic categories (among others mammals, birds, reptiles for animals and algae, mushrooms for plants) which seem highly heterogeneous. However, in globally assessing the peaceful cohabitation hypothesis between human habitat and animal and plant species, they serve the purpose of being aggregate proxies for the threads to natural habitat. Substantive contributions separating taxonomic categories can be found in the existing literature (Naidoo and Adamowicz, 2001; Perrings and Halkos, 2010 and Freytag et al., 2012).

*Explanatory variables:* Among the threats to natural habitat, the UICN also lists habitat disturbances, overexploitation and pollution. The existing literature helps identify the following factors: Income per capita, intensive agricultural production and trade openness (Cabo, 1999; Alam and Quyen, 2002; McPherson and Nieswiadomy, 2005 and Mills and Waite, 2009); human population growth and urbanization (McDonald et al., 2008). Thus, to capture human activities, we use income per capita evaluated in purchasing power parity (PPP, in 2011 $), population density, trade and industry and agriculture added values (in % of GDP). Further control variables such as the mean years of schooling, the share of forest land, foreign direct investments (net inflows) and climate zones are also included. These explanatory variables are extracted from the World Development Indicators. The dataset includes 179 developed and developing countries and covers the period between 2007-2014.

[5] See the IUCN Key Documents on the categories and the classification criteria for further details and summary of the 5 criteria (A-E) used to evaluate whether a taxon belongs in an IUCN's red list.

Table 1: Descriptive statistics

| Variables | Units | Mean | S.D. | Min. | Max. | Obs. |
|---|---|---|---|---|---|---|
| lnGDP per capita | $, PPP 2011 | 9.10 | 1.24 | 6.34 | 11.82 | 1210 |
| Threatened plant species | Number | 51.86 | 111.07 | 0 | 1839 | 1232 |
| Total plant species | Number | 151.88 | 199.29 | 21 | 2542 | 1232 |
| Threatened animal species | Number | 123.39 | 147.45 | 5 | 1009 | 1253 |
| Total animal species | Number | 1131.61 | 929.15 | 18 | 5733 | 1253 |
| Agriculture, added value | % GDP | 13.31 | 12.65 | 0 | 58.21 | 1103 |
| Industry, added value | % GDP | 28.52 | 13.06 | 4.00 | 78.20 | 1110 |
| Mean years of education | Number of years | 7.77 | 3.20 | 0.00 | 12.90 | 1055 |
| Foreign direct investment | % GDP | 5.586 | 11.910 | -43.463 | 255.423 | 1253 |
| Trade openness | % GDP | 92.76 | 53.45 | 19.45 | 455.42 | 1183 |
| Forest area | % of area | 32.54 | 23.88 | 0.00 | 98.46 | 1061 |
| Rents of natural resources | % of GDP | 2.57 | 5.19 | 0.00 | 43.85 | 1011 |
| Population density | $1000/km^2$ | 0.32 | 1.55 | $1.69e-3$ | 19.07 | 1235 |
| Agricultural land | % of land area | 40.291 | 21.69 | 0.453 | 84.642 | 1253 |
| Control for corruption | Index | -0.08 | 0.99 | -1.92 | 2.52 | 1253 |
| Goods and services expense | % of expense | 17.48 | 11.93 | 2.21 | 75.73 | 887 |

Notes: Number of countries = 179; period: 2008-2014; number of observations: 1253. The counts of animal and plant species have been taken from "Red List Category Summary" and include for animals the number of identified vertebrates (amphibians, birds, fish, mammals, reptiles) and invertebrates (insects, molluscs, crustaceans, corals and others). For plants, the counts include mosses, algae, mushrooms among others.

Table 1 reports descriptive statistics of the main variables involved in our study. Thereby, one notices high values in the standard deviation (S.D.) of series on animal and plant species, indicating the dispersed character of the considered sample.[6] The highest levels in per capita GDP are observed in Macau, Qatar and Luxembourg. Regarding threatened species, the highest values are observed in the USA and in Ecuador; the fastest population growth rates are observed in Qatar (2008-2010) and Oman (2010-2013). By focusing only on income and the number of threatened species, high-income countries seem to show relatively less threatened species. In addition, variables about government expenses on goods ans services, political institutions and human capital are also involved in the analysis.[7] In particular, our dataset includes an indicator of corruption and the level of education. The former is considered to be reflecting the institutional quality of countries whereas the latter broadly traduces the average level of schooling, hence human capital at country level.

[6] The series on trade are obtained computing the share of exportations and importations in GDP

[7] The series on expenses are share of "all government payments in exchange for goods and services used for the production of market and nonmarket goods and services" (IMF, Government Finance Statistics).

2.2. Data on threatened species

Eppink et al. (2007) and Bartkowski et al. (2015) discussed the complexity and the multidimensionality of the concept of biological diversity which justifies the existence of several proxies. Thus, using counts of threatened species as indicator of natural habitat destruction is feasible but implies non-standard modeling techniques, as the key distributional assumptions (normality and homoscedasticity) are not fulfilled for applying standard linear modeling techniques (Hoffmann, 2004 and Cunningham and Lindenmayer, 2005). Thus, it is important to preliminary have an insight into the count data, the number of threatened animal and plant species. For this purpose, in addition to Table 1, we propose a histogram of our series on threatened animal and plant species which provides some details regarding the symmetry or skewness of the distribution. Figure 1 indicates that the series on our response variables (counts of threatened species) are not symmetrically distributed but are rather right-skewed. Modeling such series requires some appropriate econometric techniques that will be discussed in Section 4.

(a) Animal species

(b) Plant species

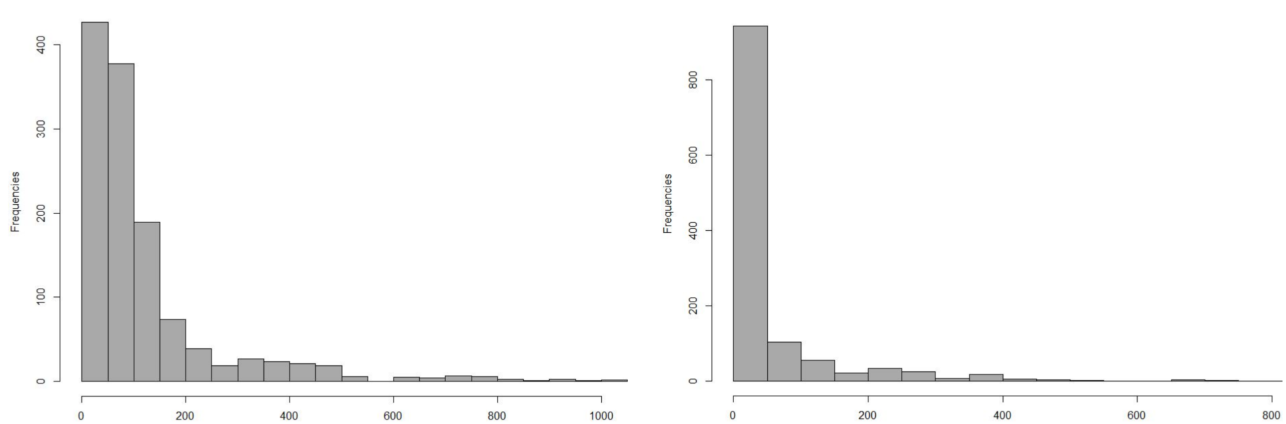



Figure 1: Histogram of counts on threatened animal and plant species

## 3. The income and threatened species nexus

As a parametric specification could be misleading in investigating the shape of a complex relationship, the following proposes a prior non-parametric analysis uniquely focused on the relationship between our variables of interest, per capita GDP and the number of threatened animal and plant species.

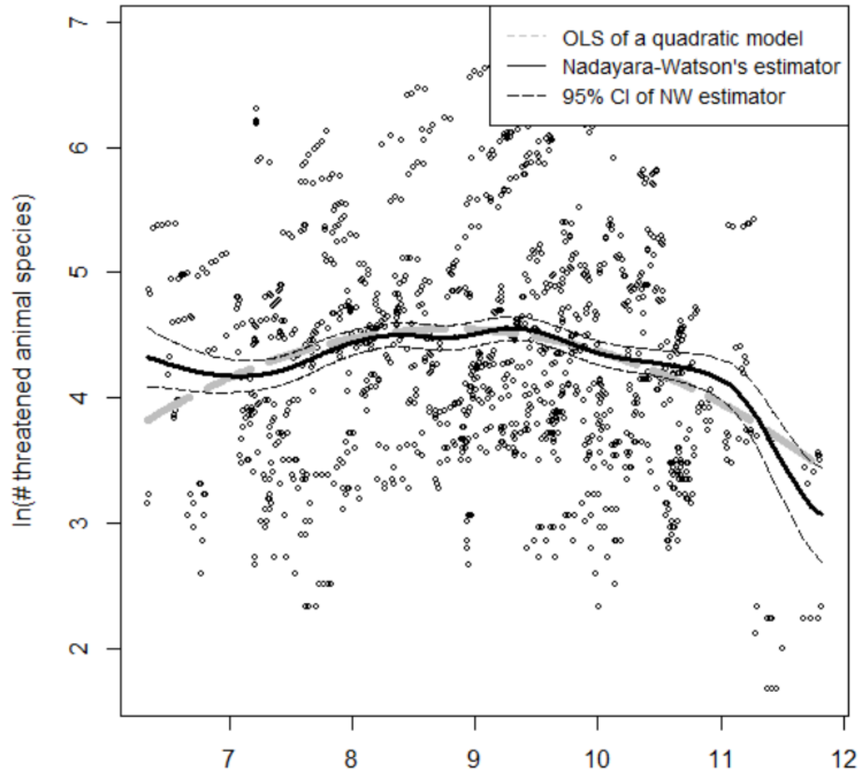
Variance stabilizing transformations for regression models in exponential families are often used to modify count data, making non-parametric regression procedures easily feasible (Brown et al. 2010). Main contributions to the topic are made by Anscombe (1948), Hoyle (1973), Efron (1982), and Brown et al. (2010) in the literature on count data transformations. Using data on threatened species, Dietz and Adger (2003) and Mills and Waite (2009) divided the number of species by the country size, Hoffmannn (2004) by the total number of species whereas Perrings and Halkos (2010) used a log-transformation. Following the latter, we modify our count data using $\log(y_{it}+k)$ operator as proposed by Anscombe, with $0 \leq k \leq 1$.[8] Thereby, the Negative Binomial (NB) mean-variance relation, $\sigma^2 = \mu + \frac{1}{k}\mu^2$, is used to compute $k$. Exploiting the log-transformed counts, the Nadayara-Watson (or local constant kernel) estimator is applied to the non-parametric regression of $\log(y_{it} + \hat{k})$ on log-income per capita ($x_{it}$).

The main objective is to directly estimate $m(x_i) \equiv E[\ln(y_{it} + \hat{k}|x_{it})]$. Moreover, as the ecological modernization theory predicts that environmental harms will slow down and even be compatible along economic development, using for response variable log-modified or time-averaged counts should permit to validly investigate the income and threatened species nexus. The results of the local constant kernel estimator are displayed in Figure 2 for both animals and plants species.

In the case of animal species, Figure 2 shows a slight upward trend in the number of threatened species for low income levels. This trend becomes downward after a certain level in log-income per capita, the turning point being around the mean of the sample. Hence, in low-income countries, there is a positive link between income and threatened animal species while the results point to a negative one in high-income countries.

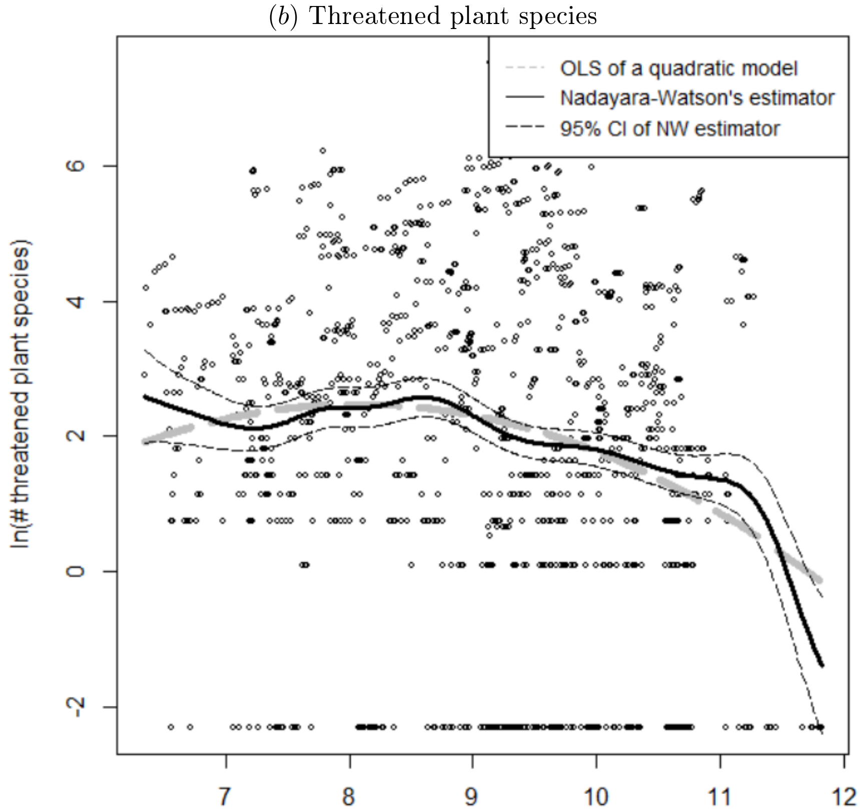
[8] Lambert et al. (2010) and Cameron and Trivedi (1998) proposed different approaches in estimating $k$.

(*a*) Threatened animal species




lnGDP per capita

(*b*) Threatened plant species




lnGDP per capita

Figure 2: Non-parametric model of log-modified count on threatened species and lnGDP per capita.

Regarding threatened plant species, the regression lines show similar patterns. For low income levels, no clear conclusion can be made, as the confidence interval is quite large. After the sample mean of log-income per capita, circa 9.10 $, the results are analogous to those obtained in the case of animal species, suggesting that in high-income countries, economic activities do not conflict with plant species, confirming theoretical predictions of the EKC literature. This preliminary analysis indicates that a quadratic specification should be sufficient for modeling the threatened species and GDP per capita nexus. The following Section discusses count data model.

## 4. Econometric model

To assess the drivers of species loss while testing the peaceful cohabitation hypothesis, we mainly use parametric count data regression methods. Exploring count data, the econometric literature, e.g. Cameron and Trivedi (1998, 2013), Hilbe (2011) and Winkelmann (2008), argues for the use of Poisson-gamma mixture models. Considering the number of threatened species, $y_{it}$, to be Poisson distributed, $f(y|x) = \frac{e^{-\mu}\mu^{y}}{y!}$, and assuming independence between the vector of exploratory variables, $x_{it}$, and the error term, $\varepsilon_{it}$, we start from the following model passing over individual time variabilities.[9]

$$\mu_{it} \equiv E\left[y_{it}|x_{it}\right] = \exp(x'_{it}\beta),\ i = 0, 1, \cdots N,\ t = 0, 1, \cdots T. \quad (1)$$

The regression model (1) suffers from two major issues.[10] First, Table 1 shows patterns of overdispersion in the series on threatened animal and plant species. A NB distribution releasing the mean-variance equality assumption should be considered. Second, the model assumes independence between the unobserved errors $\varepsilon_{it}$ and the regressors $x_{it}$. However, there might be a reverse causality between our variable of interest (GDP per capita) and biodiversity indicators, since production activities can be reversely explained by exploitation of natural resources and biodiversity. Such an endogeneity issue can lead to biased estimation (Cameron and Trivedi, 2013). A very straightforward and novel way to deal with that issue is by the control function approach (CFA) for non-linear models discussed in Winkelmann

[9] Our dataset having a very small T, associated with low time variability in the response variable for a relatively high number of individuals (N=179), we assume the homogeneity of the slope coefficients over time and pool the data. Econometric tests (See Baltagi and Griffin, 1997; Pesaran and Smith, 1995 and Baltagi et al.,2008) indicates that in panel data with T very small, pooled estimators are also a viable choice.

[10] Note that lnGDP per capita enters in (1) under a quadratic form, as discussed in the previous Section.

(2008) and Wooldridge (2014, 2015a).

Let $x_1$ be an endogenous regressor, GDP per capita for instance, and also a valid instrument, $Z_1$, the CFA proposes a first-stage regression whose residuals are introduced back into the conditional mean equation at the second stage estimation. The first stage regression is:

$$x_1 = \rho Z_1 + x'\delta + v, \text{ where } v|x, Z \sim N(0, \sigma^2 I). \tag{2}$$

The second stage regression considers the conditional mean (1) augmented by $\hat{v}_{it} \equiv x_1 - \hat{\rho} Z_1 - x'\hat{\delta}$, which is viewed as an additional explanatory variable:

$$\mu_{it} \equiv E\left[y_{it}|x_{it}, x_{1,it}\right] = \exp(x'_{it}\beta + \beta_1 x_{1,it} + \beta_v \hat{v}_{it}) \tag{3}$$

Wooldridge (2015a) mentions that introducing the first-stage residuals in equation (3) controls for the endogeneity of $x_1$. Moreover, it serves the purpose of producing a heteroskedasticity robust endogeneity test.[11] Relying on this control function approach in count data models, parameters $\beta$, $\beta_1$ and $\beta_v$ can be estimated using maximum likelihood.

## 5. Estimation results

### 5.1. Tests for overdispersion

Before estimating the parameters of regression models relating the number of threatened species to income per capita and other determinants, it seems important to test for overdispersion. This is testing the mean-variance equality assumption of the Poisson distribution, as huge differences are observed between the mean and the variance of the series on threatened animal and plant species (Table 1). Dean and Lawless (1989) propose a $Z$-score test which seems straightforward to implement. Applying this test to our different model specifications, we find results suggesting overdispersion in the series on threatened species. The test results (in Tables 2) indicate that in modeling the number of threatened animal and plant species, overdispersion should be accounted for.

### 5.2. Determinants of biodiversity loss and regional heterogeneities

#### 5.2.1. Determinants of biodiversity loss

Considering the counts of threatened species to be NB distributed, the econometric literature indicates that NB estimates are asymptotically normal, efficient and unbiased. However,

[11] The null hypothesis $H_0$: $\beta_v = 0$ corresponds to the exogeneity of $x_1$. See also Wooldridge (2014)

this unbiasedness is violated in presence of endogeneity issues. Estimating the parameters of the different specifications, we address the endogeneity issues related to our variable of interest, per capita GDP, by exploiting the CFA (Wooldridge, 2014, 2015a) discussed above. Thereby, as instrument for GDP per capita, we rely on political institutions and government expenditures, mainly on the index for corruption and the share of goods and services expense (% of expense). The latter seem to be good instruments as they show high correlations with log-GDP per capita and are less likely to be included among control variables.[12]

Our dataset having a very small $T$ characterized with low time-variability in the response variable for a relatively high number of individuals $N$, we rely on pooling the data. Table 2, in addition to over-dispersion tests and first stage regressions, reports the results of estimating the parameters of different NB model specifications. Observing the results for both animal and plant species, one notices that compared to a linear fit a quadratic specification in lnGDP per capita fits better the data. This corroborates the discussion in Section 3 which suggests a non-linear modeling for the economic growth and threatened species nexus. By comparing information criteria, Model 3 shows larger predictive power and therefore will be considered discussing the peaceful cohabitation assertion.

- Animal species: Our results broadly indicate that human habitat characteristics are not neutral in biodiversity loss, as income per capita and human population density significantly affect the number of threatened animal species. More precisely, our parametric estimations reveal a non-linear relationship between income per capita and threatened animal species implying that economic activities increasingly threaten biodiversity in low-income countries, while it decreasingly does in high-income countries. Such a result, known in the existing empirical literature as the presence of an EKC relationship, seems to hold as the parameter of the quadratic term remains statistically significant throughout model specifications 2 and 3. Though parametric model specification could be misleading, the results support the conclusion based on Figure 2 regarding the existence of an inverted U-shaped relationship between income per capita and the counts of threatened animal species.

[12]Both instruments poorly perform in regression models for threatened species.

Table 2: Results of estimating negative binomial models for threatened species

| | Second stage regressions | | | | | |
|---|---|---|---|---|---|---|
| | (a) Animal species | | | (b) Plant species | | |
| Covariates / Models | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| Intercept | 4.209*** (.575) | −4.968** (2.479) | 1.390 (2.301) | 7.197*** (.853) | 14.468*** (3.171) | −3.428 (4.813) |
| lnGDP per capita | .065 (.062) | 2.063***(.556) | .958** (.445) | −.362*** (.091) | 4.318*** (.813) | 1.740* (.925) |
| Squared lnGDP per capita | | −.107*** (.031) | −.055** (.022) | | −.250*** (.045) | −.085** (.045) |
| Total species identified | | | .563*** (.038) | | | .004*** (.000) |
| Climate zone | | | −.016*** (.002) | | | −.066*** (.005) |
| Forest area | | | .002* (.001) | | | .012*** (.003) |
| Mean years of schooling | | | −.017** (.007) | | | −.008 (.016) |
| Rents of natural resources | | | −.001 (.003) | | | −.005 (.007) |
| Foreign direct investment | | | .125 (.343) | | | −.013 (.454) |
| Agriculture, value added | | | −.025*** (.006) | | | −.024 (.015) |
| Industry, value added | | | −.010** (.005) | | | .032 (.079) |
| Trade | | | −.006*** (.001) | | | −.012*** (.001) |
| Population density | | | .033** (.013) | | | .013*** (.003) |
| $\hat{v}_{GDP\text{p.c.}}$ | .070 (.084) | −068(.076) | .286** (.087) | .762*** (.158) | .356** (.137) | .174 (.232) |
| Number of obs. | 872 | 872 | 723 | 855 | 980 | 631 |
| AIC criterion | 10157 | 10137 | 7562.5 | 7356.8 | 8521 | 4869.4 |
| Log likelihood | -5074.343 | -5063.699 | -3766.235 | -3674.379 | -4255.516 | -2419.708 |
| | **First stage regressions** | | | | | |
| Regressor: lnGDP p.c | Model 1 & 2 | | Model 3 | Model 1 & 2 | | Model 3 |
| Intercept | 9.657*** (.137) | | 9.096*** (.320) | 9.657*** (.137) | | 9.104*** (.309) |
| Index of Corruption | .687*** (.059) | | .397*** (.041) | .687*** (.059) | | .388*** (.039) |
| Government expenses | −.024*** (.008) | | −.006** (.003) | −.024*** (.008) | | −.007* (.004) |
| Total species identified | | | .066* (.034) | | | .044*** (.016) |
| Climate zone | | | .012*** (.002) | | | .018*** (.003) |
| Forest area | | | −.059 (.215) | | | .036 (.217) |
| Mean years of schooling | | | −.010 (.014) | | | −.007 (.014) |
| Rents of natural resources | | | .004 (.006) | | | .004 (.006) |
| Foreign direct investment | | | .097 (.095) | | | .011 (.009) |
| Agriculture, value added | | | −.048*** (.006) | | | −.048*** (.006) |
| Industry, value added | | | .011** (.005) | | | .010** (.005) |
| Trade | | | .014 (.009) | | | .013 (.088) |
| Population density | | | .089 (.279) | | | .023 (.284) |
| Number of obs. | 872 | | 639 | 872 | | 631 |
| Adjusted R-squared | .515 | | .863 | .515 | | .865 |
| | **Tests for overdispersion** | | | | | |
| Z-score | 124.860 | 125.190 | 30.705 | 124.860 | 125.190 | 30.705 |
| *p*-value | <2e-16 | <2e-16 | 1.19e-09 | <2e-16 | <2e-16 | 1.19e-09 |

Note. Dependent variables are the counts of threatened animal and plant species. Bootstrapped standard errors in brackets. Unbalanced panel data, with $N = 179$ and $T = 7$. "***", "**" and "*" respectively stand for significance level at 1, 5 and %. $\hat{v}_{GDP\text{p.c.}}$ stands for the control function relatively to our variable of interest, lnGDP p.c. Regarding the first stage regressions, dependent variable is lnGDP per capita. Robust (HAC) standard errors in brackets. For the overdispersion tests, the null hypothesis is equidispersion. Table A1-2 in Appendix reports results using mean-centered lnGDP per capita and controlling for country dummy.

In addition to the peaceful cohabitation hypothesis, results also indicate that trade and the rents of natural resources (mainly oil, natural gas, coal and mineral rents) do not harm animal species. Controlling for species richness and climate by using the total number of animal species identified and distance from equator indicates that more threatened animal species lie in species-rich regions while less are found in countries far from the equator. These results imply that in tropical zones, where biodiversity mostly lies, relatively high species are threatened by extinction.

With regard to the theoretical results by Polasky et al. (2002) and by Alam and Quyen (2007) showing that trade openness, agricultural production lead to deforestation and species loss in the South, we control for agricultural production, trade and forest cover. Doing so, forest size appears to be positively related to number of threatened animal species. As forests largely serve as natural habitat for species, it is not surprising to observe that the larger forest size there is in a country, the more threatened species it shelters, due to its potential species richness. Concerning trade and agricultural production, our results globally diverge from Alam and Quyen (2007). Agriculture and openness to trade are not to blame for threatening animal species, at least when considering the global sample. Likely, separating countries according to income level and considering geographical blocks will help more clearly apprehend the role of trade in endangering species. A final interesting result on the case of animal species is the role of human population growth. Population density is found to be positively linked to the number of species at threat, meaning that the higher human population is, the more threatened animal species there are. Such as result underlines a possible competitive exclusion over habitat between human population and animal species.

- Plant species: The results presented in Table 2 (b) are derived using the same methodological approaches (model specification and instrumental variable) as in the case of animal species. Here also, comparing the information criteria indicates that NB models including lnGDP per capita and its quadratic form correspond much better to the data. Thus, observing Model 3 strengthens conclusions regarding an inverted U-shaped relationship between the number of threatened plant species and income per capita, as GDP per capita is positively related to the response variable, whilst its squared form shows a negative link. Likewise the patterns observed in Figure 2, the outputs of this parametric analysis support a declining trend in the numbers of threatened species after a certain level of per capita GDP.

Controlling for the total number of species identified and climate zone, the estimations show results revealing that more threatened plant species are found in tropical and species-rich countries. Also, the positive and significant effects of forest observed here likely implies that the larger forest share countries have, the more plant species-rich they are, and consequently the more threatened plant species they shelter. Once again, agriculture production, trade openness and the exploitation of natural resources are globally not to blame for threatening plant species. Human population dynamics, captured by population density, is positively and significantly linked to the number of threatened plant species, supporting our first argument regarding a possible conflicts over habitat between human population and other biological species.

It is noticeable that this parametric analysis supports the patterns in Figure 2 regarding the threatened species and income nexus, implying that a peaceful cohabitation between economic activities and biodiversity is possible in high-income countries. Furthermore, the results help identify human population growth as driving biodiversity loss, providing evidence of a possible global competition between human population and biodiversity over habitat.

5.2.2. Regional heterogeneities

In order to investigate whether heterogeneities exist over regions, this analysis is performed using data classified by continent. Table 3 presents the results of Model 3 by continent. Thereby, we also use the CFA in solving for potential endogeneity biases.

- Africa: Being mostly in tropical zones and largely covered by forest, animal and plant species-rich African countries are also those sheltering relatively high numbers of species threatened by extinction. Besides these natural factors, population growth in Africa appears to be threatening its biodiversity, suggesting a conflicting cohabitation between human population and biological species in this continent.

- America: A non-linear relationship is observed between the number of threatened animal and plant species and income. Contrary to plants species which appear to be largely threatened by extinction in temperate climate zones, our results show that larger forest covered American countries shelter lower threatened animal species. Moreover, no conflicts is observed between agricultural production, trade, population density and biological species.

- Asia: The results suggest an inverted U-shaped curve between the number of threatened species and income per capita, similar to those observed in Figure 2. In addition, species-rich and large forest covered Asian tropical countries shelter more threatened animal and plant species. Also, agricultural sector and population density are not significantly harmful to biodiversity in Asia.

• Europe: Regarding animal species, the result points to a seemingly inverted U-shaped, while a U-shaped relationship appears for plant species. Besides income, no further factor is found to be harmful to species diversity except educational level for animal species and industrial production for plants. The latter result indicates that relatively high plant species are at threat in European countries which larger share of industrial value-added in GDP.

To complete this heterogeneity analysis, we disentangle countries according to income levels, by distinguishing countries with incomes higher than the sample median (9.259 $) from countries with lower incomes.

• High income countries: An inverted U-shaped relationship appears between income per capita and threatened species, supporting a possible harmonious cohabitation between biological species and human economic activities during the development process. The more species-rich high-income countries are, the more threatened animal species they shelter. Among our control variables, it is to observe that trade and industrial production negatively affect counts of threatened species in developed countries.

• Low income countries: Focusing on threatened plant species, our results signal a significant U-curve implying that more animal species are threatened by extinction with increases in income per capita in developing countries, which contradicts the peaceful cohabitation hypothesis. Also natural resources exploitation and human population growth also affect biodiversity in low-income countries. Finally, industrial production and trade positively drive species loss.

The regional analysis of the drivers of species loss has pointed out some interesting regional heterogeneities. First, for both species group, it is observed that there is a peaceful cohabitation between economic expansion and animal and plant species in high-income countries. Second, on the role of human population, we found that population growth drives biodiversity loss only in low-income countries as in Africa. Finally, contrasting results appear regarding trade and industrial production activities.

Table 3: Regional heterogeneities: Estimation of NB models for animal and plant species

**(a) Animal species**

| Covariates / Models | Africa | America | Asia | Europe | High-income | Low-income |
|---|---|---|---|---|---|---|
| Intercept | 12.064**(4.802) | 4.021***(.813) | −7.021**(3.460) | −1.301**(.519) | −3.940***(.772) | 1.154**(.476) |
| lnGDP per capita | −1.036(1.001) | −5.671***(.002) | 2.890***(.594) | 3.861**(1.220) | 8.836***(1.360) | −1.410 (1.059) |
| Squared lnGDP per capita | .016 (.057) | .241***(.084) | −.167***(.027) | −.185***(.062) | −.433***(.064) | .059(.060) |
| Total animal species | .654***(.099) | .410***(.041) | .452***(.056) | .745**(.283) | .547***(.031) | .547***(.062) |
| Climate zone | .021***(.006) | −.016* (.009) | −.028***(.005) | −.065***(.009) | −.024***(.003) | −.005 (.004) |
| Forest area | .055 (.226) | −.009***(.003) | .007***(.002) | −.002 (.002) | −.005***(.001) | .006*** (.002) |
| Mean years of schooling | −.011 (.019) | −.083***(.021) | −.002 (.019) | .045* (.024) | .019 (.012) | .007 (.020) |
| Rents of natural resources | .007(.006) | .006 (.006) | −.004 (.003) | −.001 (.005) | .002 (.003) | −.018**(.005) |
| Foreign direct investment | .014 (.011) | −.021*(.012) | −.078 (.247) | −.002 (.002) | −.003 (.003) | .017**(.008) |
| Agriculture, value added | −.054***(.014) | −.147***(.002) | −.027*(.016) | −.007 (.013) | −.004 (.016) | −.030 (.093) |
| Industry, value added | −.018*(.009) | −.022**(.008) | .006 (.005) | −.013 (.005) | −.015***(.004) | .011***(.009) |
| Trade | −.002(.002) | −.007***(.002) | −.007***(.001) | −.005***(.001) | −.006***(.001) | −.001 (.002) |
| Population density | .001***(.000) | −.003***(.000) | .031 (.187) | −.068** (.023) | −.015 (.015) | .091**(.029) |
| $\hat{v}_{GDP\ \text{p.c.}}$ | .838**(.309) | 1.054***(.257) | .082 (.190) | −.143 (.141) | .383**(.136) | .578**(.261) |
| Number of obs. | 242 | 137 | 211 | 229 | 421 | 425 |
| AIC Criterion | 2519.6 | 1400.8 | 2170.6 | 1895.2 | 4199.5 | 4514.2 |
| Log Likelihood | -1243.787 | -684.407 | -1069.278 | -931.592 | -2083.737 | -2241.109 |

**(b) Plant species**

| Covariates / Models | Africa | America | Asia | Europe | High-income | Low-income |
|---|---|---|---|---|---|---|
| Intercept | 4.123 (7.990) | 6.225***(1.524) | −3.162**(1.234) | 6.727**(2.769) | −1.028**(.345) | 2.177**(.688) |
| lnGDP per capita | −.621 (1.722) | −8.089**(3.143) | 7.155***(2.150) | −11.684**(5.366) | 1.762**(.663) | −4.260**(1.502) |
| Squared lnGDP per capita | .019 (.098) | .239 (.168) | −.391***(.101) | .547**(.258) | −.085***(.032) | .183**(.082) |
| Total plant species | .008***(.001) | .002***(.000) | .002***(.000) | .010***(.001) | .028 (.059) | .018 (.015) |
| Climate zone | −.017 (.013) | .035**(.017) | −.036**(.011) | −.051***(.014) | −.003** (.001) | .003 (.004) |
| Forest area | .013**(.005) | .022**(.007) | .024***(.006) | −.021***(.005) | −.001**(.000) | .012***(.002) |
| Mean years of schooling | .067* (.038) | −.077**(.044) | .234***(.061) | −.067*(.041) | −.030***(.005) | −.051**(.017) |
| Rents of natural resources | −.019 (.012) | −.015 (.018) | −.026**(.024) | −.114***(.029) | .001 (.001) | .022*(.008) |
| Foreign direct investment | .008 (.013) | .007 (.029) | .009 (.07) | −.029**(.015) | .002* (.001) | −.029**(.008) |
| Agriculture, value added | −.011 (.020) | −.318***(.044) | .004 (.057) | −.286***(.052) | .009 (.006) | −.059***(.011) |
| Industry, value added | .025 (.017) | −.034* (.020) | .020 (.013) | .073***(.016) | −.017 (.018) | .013 (.009) |
| Trade | .001 (.005) | −.015***(.004) | −.007**(.003) | −.014***(.003) | −.014***(.002) | .005***(.001) |
| Population density | .002**(.001) | −.003**(.002) | −.001*(.000) | −.001 (.001) | .136 (.065) | −.103 (.235) |
| $\hat{v}_{GDP\text{p.c.}}$ | .610 (.572) | 1.624**(.665) | −2.376**(.638) | 1.264***(.439) | .049 (.072) | .795**(.257) |
| Number of obs. | 242 | 137 | 208 | 225 | 414 | 411 |
| AIC Criterion | 2031.7 | 1390 | 1754.7 | 979.53 | 2067.3 | 2579.8 |
| Log Likelihood | 999.836 | -679.019 | -861.346 | -473.765 | -1017.635 | -1273.923 |

Notes: Dependent variables are counts of threatened animal and plant species. Bootstrapped standard errors in brackets. "***", "**" and "*" respectively stand for significance level at 1, 5 and 10%.

## 6. Discussion: Beyond the apparent peaceful cohabitation

Our analysis globally reveals non-linearities in the income and threatened species nexus, implying the existence of an EKC for threatened animal and plant species. In addition, it provides some hints on the opposite role played by industrial production and trade: While both variables negatively affect the number of endangered species leading to a possible peaceful cohabitation in developed countries, they positively drive biodiversity loss in low-income countries. Such findings enlightens some of the mechanisms behind the patterns depicted by Figure 2.

Firstly, it is to notice that high-income countries, mostly non-tropical countries, shelter relatively few animal and plant species (Polasky et al., 2005 and Giam, 2017). Further, our analysis shows that the more species-rich countries are, the more threatened species they shelter, implying that compared to developing countries, high-income countries hold relatively fewer threatened animal and plant species. Secondly, extinct species can not be recovered, making ecological modernization theory-based projections somewhat fragile, when it comes to biodiversity. In this perspective, species loss that has occurred in early stages of economic development contributes to the comparative species richness currently observed. With regard to the peaceful cohabitation hypothesis, both arguments point to a relative species poverty in high-income countries, providing first explanations to the declining counts of threatened animal and plant species observed with increasing income level.

The recent critical EKC literature (Aslanidis, 2009; Wagner, 2008, 2010; Kaika and Zervas, 2013 and RodrÃguez et al., 2016) and works by sociologists on the treadmill of production (Schnaiberg, 1980; Gould et al., 2004 and 2008) as well as on ecologically unequal exchange theory (Jorgensen, 2009, 2016 and Jorgenson and Dick, 2010) go a step ahead by shedding light on the mechanisms behind the observed trends. The former perspective discusses the existence of perpetual conflicts between economic expansion and nature while the latter considers the role of international trade in exporting environmental harms. As human habitat endlessly uses natural resources to produce consumption goods and generates wastes, it continually destroys natural habitat, making any peaceful cohabitation between natural and human habitats hardly possible. In this context, a strategic externalization of ecosystem damaging production activities and even delocalizing environmental unfriendly manufactures to developing countries may lead to an EKC relationship in the sense that such economic processes only displace environmental harms and habitat destruction to developing countries. Similar conclusions are noted in the theoretical results by the North-South general equilibrium model by Polasky et al. (2002) and Alam and Quyen (2007). Empirical works by Jorgenson and Dick (2009) and Hornborg (2012) show that trade's structure (mainly flow of primary sector goods) may help high-income countries to partly pass their demand-based ecological impact to developing countries.

Our analysis distinguishing low and high-income countries, the estimated parameters for trade and industrial production somewhat support the ecologically unequal exchange theory. Based on these findings, one can legitimately argue that industrial production in poor countries (mostly in primary sector and its exportation) threatens animal and plant species, whereas both tertiary sectors production and trade appear to be ecosystem friendly in high-income countries. In addition to the disparate role of human population in threatening natural habitat only in low-income countries, these likely are some of the mechanisms allowing a decreasing threat to species loss with income level, suggesting a peaceful cohabitation between habitats in high-income countries.

## 7. Concluding remarks

The existing literature on the sources of biodiversity loss strongly underlines conflicts between livings species, a competitive exclusion. In relation to economic and population growth, this implies that human society and economic activities, human habitat, grow at the expense of non-human species, thus biodiversity.[13] Consequently, this paper contributes to the empirical literature on the economic causes of biodiversity loss by globally investigating whether there is a peaceful cohabitation between human habitat and nature, targeting animal and plant species.

Applying count data regression techniques, we find that income per capita significantly affects the number of species at threat. More precisely, our results suggest that the link of our indicator of biodiversity loss to income is not linear but rather depicts a seemingly inverted U-shape. The latter globally implies that species loss tends to slow down with economic development, suggesting a possible peaceful cohabitation between habitats in high-income countries. Such a result can be linked to the patterns in the Living Planet Index (LPI), observed between 1970 and 2005 (see Figure A2). In tropical climate zones, where developing countries mostly lie, a rapidly decreasing trend in LPI is observed contrarily to temperate

[13] The concept is actually known as *Gause's law* and can be found in Czech (2004, 2008).

climate countries where an upward trend is noticed. Furthermore, a global-level investigation uniquely focused on the functional form of the relationship between both factors, namely income per capita and the number of threatened species, helps see that biodiversity is degraded in developing countries while fewer species are at threat in high-income countries. Besides income which depicts an inverted U-shaped relationship to threatened species, human population growth measured by population density globally conflicts with animal and plant species. Overall in developed countries, a peaceful cohabitation with biological species appears to be quite possible as our outcomes definitely show a decreasing trend.

Distinguishing high from low-income countries reveals distinct results regarding the role of trade and industrial production, providing some hints about the mechanisms behind the peaceful cohabitation. While trade and industrial production help reduce the number of threatened species in high-income countries, they are found to be driving biodiversity loss in developing countries. This likely results from the primary sector production process largely based on natural resources extraction and exportation in low-income countries.

Our study on the peaceful cohabitation between natural and human habitats can be extended in different ways. A promising extension could be in proposing a mathematical population-resource model for resources extensive economies (Africa for instance) and then using available data on biodiversity and population growth to simulate the dynamical evolution of population and animal and plant species as done in Easter-Island related literature. This is left to future researches.

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## Appendix

Table A1: Results of NB estimation controlling for country-dummies

| | (a) Animal species | | | (b) Plant species | | |
|---|---|---|---|---|---|---|
| Covariates / Models | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| Intercept | $4.924^{***}(.485)$ | $-2.338(1.851)$ | $2.498$ $(2.223)$ | $8.751^{***}(.649)$ | $-3.488$ $(2.925)$ | $-8.639^{*}(4.812)$ |
| lnGDP per capita | $-.029$ $(.054)$ | $1.557^{***}(.418)$ | $.643^{*}$ $(.409)$ | $-.548^{***}(.068)$ | $2.097^{***}(.638)$ | $2.781^{***}(.908)$ |
| Squared lnGDP per capita | | $-.085^{***}(.023)$ | $-.041^{**}(.018)$ | | $-.141^{***}(.034)$ | $-.162^{***}(.045)$ |
| Total species identified | | | $.577^{***}(.033)$ | | | $.438^{***}(.039)$ |
| Climate zone | | | $-.013^{***}(.002)$ | | | $-.045^{***}(.007)$ |
| Forest area | | | $.002^{*}$ $(.001)$ | | | $.012^{***}$ $(.002)$ |
| Mean years of schooling | | | $.007$ $(.012)$ | | | $.089^{**}(.039)$ |
| Rents of natural resources | | | $-.002$ $(.003)$ | | | $-.013(.014)$ |
| Foreign direct investment | | | $-.016$ $(.273)$ | | | $.102$ $(.535)$ |
| Agriculture, value added | | | $-.027^{***}(.007)$ | | | $-.028^{*}$ $(.015)$ |
| Industry, value added | | | $-.006$ $(.004)$ | | | $.010$ $(.017)$ |
| Trade | | | $-.005^{***}(.001)$ | | | $-.009^{***}(.003)$ |
| Population density | | | $.302^{*}(.128)$ | | | $.272(.471)$ |
| $\hat{v}_{GDP\text{p.c.}}$ | $.138^{**}(.067)$ | $.014$ $(.068)$ | $.188^{**}$ $(.092)$ | $.876^{***}(.112)$ | $.632^{***}$ $(.120)$ | $.123$ $(.194)$ |
| *Country dummy* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| Number of obs. | 1210 | 1210 | 846 | 1190 | 1190 | 837 |
| AIC criterion | 14050 | 14034 | 8856.2 | 10484 | 10473 | 6774.5 |
| Log likelihood | -7020.228 | -7010.922 | -4412.087 | -5236.816 | -5230.418 | -3371.229 |

Note: See Table A2 below for comments

Table A2: NB Estimation using mean-centered per capita GDP

| | Animal species | | | Plant species | | |
|---|---|---|---|---|---|---|
| Covariates / Models | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| Intercept | $4.658^{***}$ $.080)$ | $4.771^{***}(.092)$ | $4.939^{***}(.021)$ | $-.705^{***}(.167)$ | $4.064^{***}(.072)$ | $4.373^{***}(.470)$ |
| lnGDP per capita | $-.029$ $(.053)$ | $.004$ $(.053)$ | $-.106$ $(.087)$ | $-.275^{***}(.065)$ | $-.457^{***}(.056)$ | $-.206$ $(.181)$ |
| Squared lnGDP per capita | | $-.085^{***}(.023)$ | $-.042^{**}(.019)$ | | $-.138^{***}(.031)$ | $-.146^{***}(.045)$ |
| Total species identified | | | $.577^{***}(.035)$ | | | $.443^{***}(.039)$ |
| Climate zone | | | $-.013^{***}(.002)$ | | | $-.043^{***}(.008)$ |
| Forest area | | | $.002^{*}(.001)$ | | | $.012^{***}(.002)$ |
| Mean years of schooling | | | $.007$ $(.013)$ | | | $.010$ $(.020)$ |
| Rents of natural resources | | | $-.002(.003)$ | | | $-.013(.014)$ |
| Foreign direct investment | | | $-.157$ $(3.259)$ | | | $.096$ $(.514)$ |
| Agriculture, value added | | | $-.027^{***}(.008)$ | | | $-.029^{**}(.014)$ |
| Industry, value added | | | $-.006^{*}$ $(.004)$ | | | $.011$ $(.017)$ |
| Trade | | | $-.005^{***}(.001)$ | | | $-.010^{***}(.002)$ |
| Population density | | | $.302^{**}(.138)$ | | | $.443(.466)$ |
| $\hat{v}_{GDP\text{ p.c.}}$ | $.139^{**}(.067)$ | $.014$ $(.066)$ | $.188^{**}$ $(.099)$ | $.100^{**}(.042)$ | $.621$ $(.061)$ | $.184$ $(.195)$ |
| *Country dummy* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| Number of obs. | 1210 | 1210 | 846 | 1190 | 1190 | 837 |
| AIC criterion | 14059 | 14044 | 8663.2 | 10483 | 10437 | 6790.3 |
| Log likelihood | -7025.521 | -7017.044 | -4416.592 | -5237.518 | -5231.509 | -3380.159 |

Note: Dependent variable is the counts of threatened animal and plant species. Bootstrapped standard errors in brackets. Unbalanced panel data, with n=179 and T=7. "***", "**" and "*" respectively stand for significance level at 1, 5 and %.

(a) Animal species  (b) Plant species

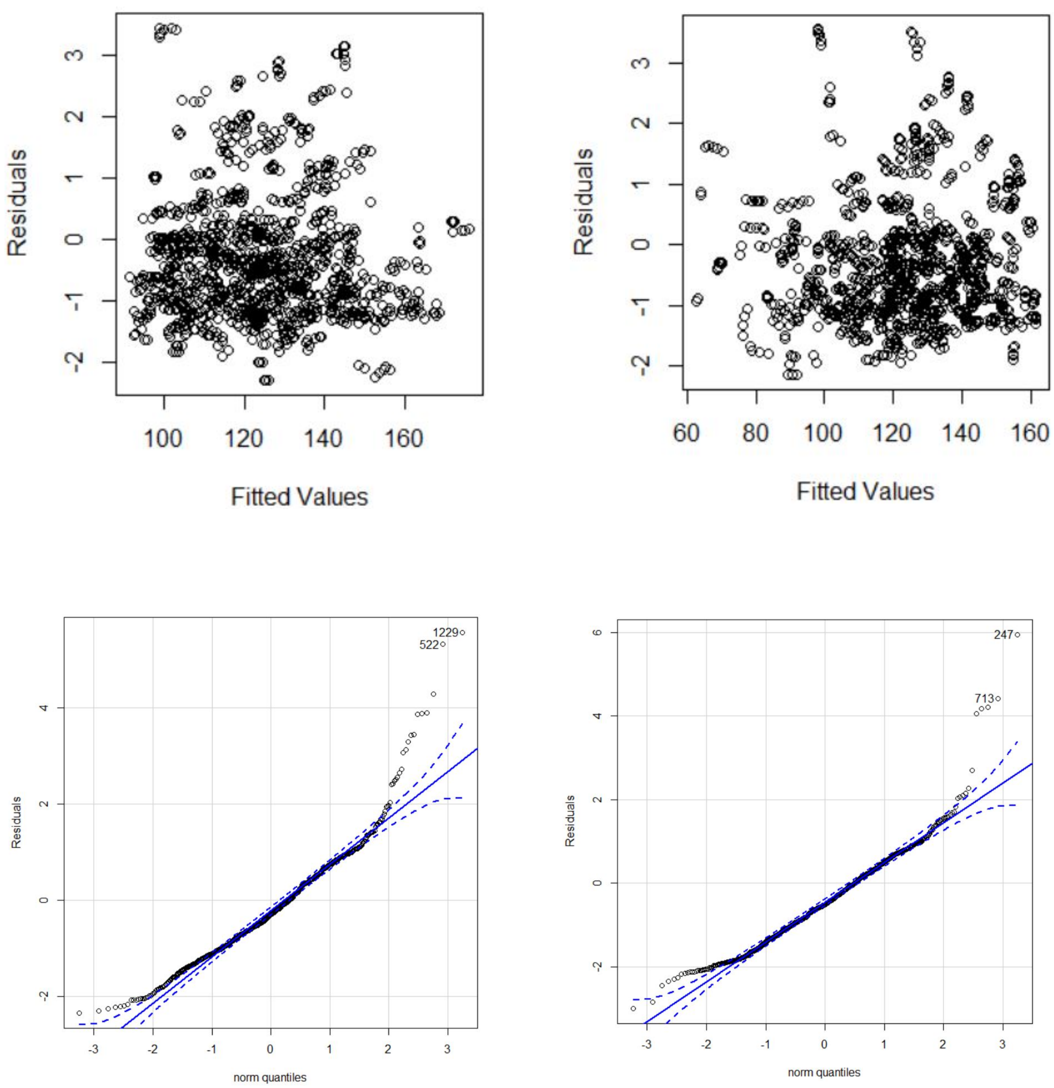


Figure A1: Table 2, Model 3 based residuals diagnostics

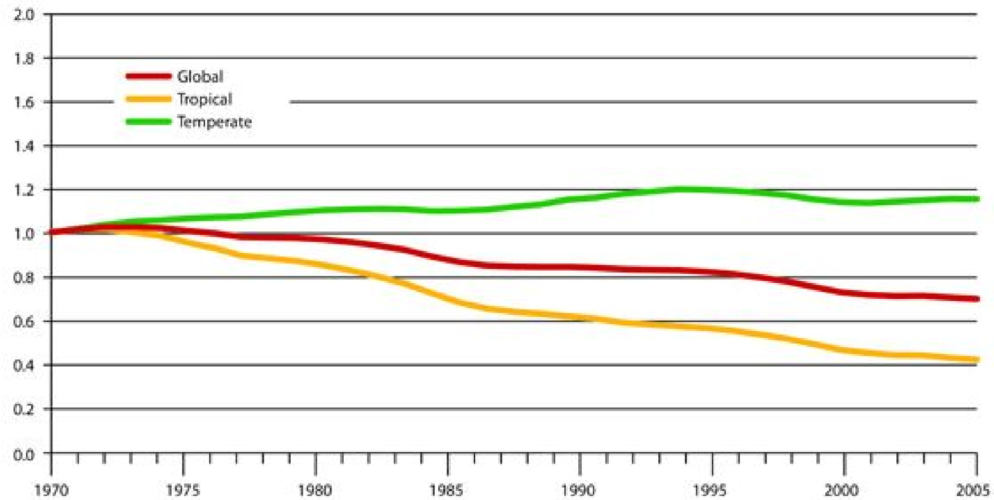


Figure A2: the Living Planet Index.
Source: Terrascope and Mission, MIT 2015

## List of countries

Afghanistan, Albania, Algeria, American Samoa, Angola, Antigua and Barbuda, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, The Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Cabo Verde, Central African Republic, Chad, Chile, China, Colombia, Comoros, Congo, Dem. Rep., Congo, Rep., Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Czech Republic, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt Arab Rep., El Salvador, Equatorial Guinea, Estonia, Ethiopia, Fiji, Finland, France, Gabon, Gambia The, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Haiti, Honduras, Hong Kong SAR, China, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kiribati, Korea, Rep., Kuwait, Kyrgyz Republic, Laos, Latvia, Lebanon, Lesotho, Liberia, Libya, Lithuania, Luxembourg, Macao, Macedonia FYR, Madagascar, Malawi, Malaysia, Maldives, Mali, Marshall Islands, Mauritania, Mauritius, Mexico, Micronesia Fed. Sts., Moldova, Mongolia, Montenegro, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russian Federation, Rwanda, Samoa, Sao Tome and Principe, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovak Republic, Slovenia, Solomon Islands, Somalia, South Africa, Spain, Sri Lanka, Sudan, Suriname, Swaziland, Sweden, Switzerland, Tajikistan, Tanzania, Thailand, Timor-Leste, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Tuvalu, Uganda, Ukraine, United Kingdom, United States, Uruguay, Uzbekistan, Vanuatu, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe.