Economic Drivers of the α-Index of the Species-Area Curve: Evidence for an EKC?

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Abstract

We study for the case of vascular plants the contribution of economic drivers towards explaining the so-called α-index of the species-area curve. This index provides a measure of observed deviation from predicted species richness. Employing explanatory variables commonly used in the empirical literature on the Environmental Kuznets Curve, we find evidence for the presence of a standard EKC-type relationship between the α -index and GDP per head. There is also evidence for a positive relationship between the α -index and the quality of political institutions. Population density and the relative size of the agricultural sector on the other hand do not have explanatory power.

1. Introduction

At least since the UN declared 2010 as the international year of biodiversity the interest in this topic rises. The threat of biodiversity loss is considered the next big challenge after CO2 reduction and reducing the chance of climate change. But is biodiversity loss just another externality like smoke or So_x? Especially: Does it react on economic growth in the same way? Answering this question is the aim of this paper.

In 1991 Grossman and Krueger where the first to discover a special relationship between pollution and growth in an economy. The relationship showed an inverted U-form and was named Environmental Kuznets Curve (EKC), after a relationship between income distribution and growth, Kuznets had discovered in 1955. From that time on, several pollutants where examined and several showed the inverted U-shape relationship.[1] Although it is agreed, that this is a statistical artifact, it is not agreed that the inverted U-shape is an inevitable path each state has to follow during development or that the EKC has any policy implication. Especially Stern et al. (1996) raised some critique against the concept and claimed, that the concept does not inform policy makers about the causal chains behind the growth and environmental damage.[2]

But obviously the EKC is a useful descriptive statistic, which shows if growth can help to solve environmental problems or if growth will just aggravate the situation.

For all EKC studies known by the author, Gross Domestic Product (GDP) per head or some similar indicator for development were chosen. Although Hopkins (1991) claimed, that development is a multidimensional issue and that economic indicators can only be one part of a development measure. Due to this there will be conducted a second analysis substituting GDP with the Human Development Index (HDI), in order to see if an EKC also exists when other dimensions of development are taken into account.

For Biodiversity several studies were made to find out, if an EKC relationship may exist – with ambiguous results. Depending on the data the shape of the curve should have a U-form and not an inverted U, because the loss of biodiversity is negative. So the curve should fall first and then rise again. Dietz and Adger (2003) and Mills (2009) examined FAO[3] data and Species Area Curve estimations for rainforest regions and did not find an EKC relationship. The former also claim, that the marginal impact of income is declining when income rises. So the resulting curve should have an L-shape. A more indirect approach was taken by McPherson and Nieswiadomy (2005), who estimated and EKC for threatened mammals on the bases of UICN data, but did not find an EKC for threatened bird species. Bhattarai and Hammig (2001) and Koop (1999) tried to solve the problem by using data of deforestation with the thesis that biodiversity loss is caused mainly by habitat loss. While the former found an EKC for tropical regions, Koop (1999) only can provide little evidence for an EKC.

In the following there will be taken α-index data from Species Area Curve estimations as an approximation for species richness to check for an EKC relationship. The Species Area Curves were estimated for vascular plant data from the years 1986 and 1995 and published by Hobohm (2000). These data are cross-sectional over 92 states all over the world. The analysis will be made by OLS-regression.[4]

1 For a survey see Dinda (2004), for a meta-analysis see Cavlovic (2000)

2 Stern (1996) p. 1159

3 Food and Agriculture Organisation

4 Stern (1996) argued that linear regressions are not feasible for cases in which feedback between dependent and

In the second part some theory concerning the EKC will be presented, followed by a short explanation of the Species Area Curve and the α-index. Subsequently, the research hypothesis will be developed. In section 5 variables and their potential influence on the α-index will be described and data sources will be mentioned. The regression models and their results will be presented in section 6 and 7. Section 8 will conclude this paper.

2. Theory of the Environmental Kuznets Curve

Although there exists no agreed model that explains the EKC, one of the most frequently used is the model of López (1994). He introduces environmental goods in a neoclassical model, where they can be used for production on the one side and on the other side are part of the utility function of individuals, which means that they can be consumed. Considering the aggregate production function $y_i = G^i(f^i(K_i, L_i; t), x_i; \tau), i = 1{,}2$ and weak separability between L and K as conventional fixed inputs and x as environmental good. τ stand for the technological change and t for the technology used. It is obvious, that as long as the environmental good does not have a price, all of it will be used in production until its marginal product is zero. So the environmental good must have a price. The optimal price would internalize all externalities produced by the environmental good. But even with some suboptimal price there will be a chance that pollution can be reduced although the economy is growing (f is rising).[5]

The other side of the model is the social welfare function specified: $\mu = \mu(R(p; f(K, L; t), x, \tau), x, p)$

Where p is the vector of output prices. If the price for x is fixed for all industries and does not change, if the willingness to pay for the environmental good changes, which can be the case by policy failure, then pollution will increase proportionally with an increase in f.[6] The same results if preferences are homothetic and policy is efficient. One way to avoid proportional increase of pollution would be technological change. But then, pollution would still increase with an increase in production.

Considering a dynamic model where factor accumulation is possible, López (1994) claims that the assumption that preferences are homothetic may hold over a certain income range, but does not hold for all income. If the income elasticity for the environmental good is larger than one, the pollution increase is no longer proportional to a growth in f. This means for 1 percent rise of income the consumption of the environmental good will increase more than 1 percent. So the demand for the environmental good rises quicker from a certain level of income, which means the willingness to pay will increase. This does not yet explain a fall in pollution level. Therefore the elasticity of substitution in the industry between pollution and non-polluting inputs has to be relatively large. Then small price changes for the environmental good will cause a change to non-polluting inputs. If the higher willingness to pay is implemented in the market, pollution will decrease.[7]

Additionally the marginal utility of income decreases with rising income. This means that people are willing to pay proportionally more for the environmental good with the next portion of income rise. How large this effect is, depends on the curvature of the utility

independent variables may exist. But as it is across-sectional analysis the author finds no way to model this feedback properly.

5 See López (1994) p. 166f. Variable t and τ are variables for technology and technological change.

6 Proof see López (1994) p. 167

7 See López (1994) p. 171

function which is also called the degree of relative risk aversion. If risk aversion is large, the price for the environmental good will rise. But risk aversion and elasticity of substitution have to reach a certain level, so that $risk\ aversion > 1/elasticity\ of\ substitition$ that pollution will decrease with growth. Usually risk aversion is estimated between 1 and 2, so that elasticity of substitution would have to be 0.5 to form the observed EKC shape.[8]

López (1994) extends his model further and considers stock effects of the environmental good. He concludes that the social shadow price has to be fully internalized and that producers have to be aware of the fact that long run extraction is proportional to a long run stock level, if the stock level should rise.[9] The social shadow price would be perfectly internalized , if the stock is privately owned. But environmental goods often are public goods or communal owned. In these cases the model depends on how the social shadow price is included in the decision of the producers, if pollution can be reduced or not. If the control over the stock grows with the economy then the price will be internalized, if not the resulting pollution can be ambiguous.[10]

So it is crucial if politics are able to reach a reasonable internalization of the shadow price, which raises the question, if people who are exposed to pollution are able to fight through higher standards of regulations, which corresponds with higher prices for the environmental good. An empirical analysis, that politics do have an influence on pollution and especially that power distribution has an influence, showed the study by Torras and Boyce in 1998.[11] Vogel (1999) also claims, that not the people with the highest income are responsible for changes in environmental politics but the “green middle-class”[12]

Andreoni and Levinson (2001) put forward a much simpler model only considering a utility function depending on pollution P and consumption C. Pollution depends on consumption and the environmental effort E a person undertakes.

$$U = U(C, P(C, E))$$

Each individual has an endowment of M one can spend C or E. P is specified as:

$$P = C - C^{\alpha} E^{\beta}$$

which indicates, that the abatement C*E works like a standard production function.[13] Analyzing the model the authors conclude that an EKC emerges, when abatement shows increasing returns to scale. This seems a quite reasonable assumption as abatement actions often have large fix costs, but cheap marginal costs. So, poor countries have to grow rich before they can afford the clean technology and avoid pollution in their production process.[14]

Gawande et al. (2001)[15] provide another explanation for the EKC. They built a model in which the input factor labor is mobile. They also claim that high-income workers have preferences for low pollution levels. So they will try to live and work in a clean

8 See López (1994) p. 172
9 See López (1994) p. 176
10 See López (1994) p. 178
11 Torras, M., Boyce, J.K. (1998) Income, inequality and Pollution: a reassessment of the Environmental Kuznets Curve.
12 Vogel (1999) p. 99
13 Andreoni and Levinson (2001) p. 272f.
14 See Andreoni and Levinson (2001) p. 278
15 Gawande, K., Berrens, R.P. and Bohara, A.K. (2001) A consumption-based theory of the environmental Kuznets curve

environment. Usually they have a higher level of education, so that they choose more freely between jobs in different regions. So they will move away from pollution and through this separation effect, in regions with high income, lower levels of pollution will be found.

Literature provides even more different models, with different aspects which could lead to an EKC relationship. One main key point often is the tradeoff between consumption and environmental good either in a production process or in individual preferences.[16]

For biodiversity it is hard to claim, that it is an input factor for production, because the pure existence of species is just used for research, even if anew product can be developed from a newly found species or serum. So a change in preferences for biodiversity would fit better at first glance. On the other hand the main reason for biodiversity loss is the loss of habitat.[17] So biodiversity loss is an externality emerging in a production process like particulate matter etc. So habitat would be the input factor and biodiversity loss the result.

The reasons for habitat destruction are manifold. Land is used for agriculture, infrastructure or urbanization etc. But before one knows the damage human activity imposes on species richness, one has to measure or at least estimate the number of species. Therefor the Species Area Curve can be used.

3. The Species Area Curve

Finding out how many species live in a certain area is often not easy because investigating each centimeter of land is too costly. But still scientists have a huge interest in comparing different regions concerning the species richness. One way to compare and predict the number of species is the Species Area Curve first described by Arrhenius in 1921.[18] He found out that the relation between area and number of species can be described as:

$c = S/A^z$ or $\log S = z * \log A + \log c$.

Where S is the number of species in the area, A is the size of the area, z is the slope of the curve and logc is the curve's intersection point with the y-axis.[19]

Having these parameters derived from different areas one can estimate the number of species that can be expected in a new area. For example one can estimate the species richness for a whole country after reviewing several locations of different sizes. Also one can compare the species density in reviewed areas by comparing the vertical distance between the collected data point of one area and the estimated Species Area Curve of different regions. That distance is called α-index.

16 See further models Roca (2003), Selden and Song (1995) McConell (1997)
17 See Ehrlich (1986) p. 21
18 Arrhenius (1921) Species and Area.
19 See Hobohm (2000) p. 17.

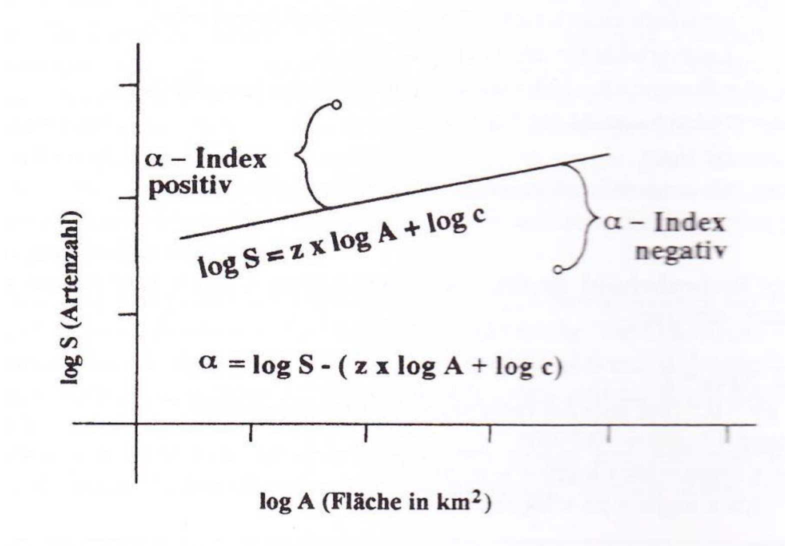

Figure 1: Species Area Curve (Hobohm (2000) p. 16)

If the data point above the regression curve, the α-index is positive and shows that the area has a higher species density than expected. The areas can be compared and one can discern if they are species rich or not without giving exact numbers of species.[20]

If there is a correlation between the species richness and several human factors like population density, size of a country's economy, one could estimate the damage humanity is imposing on biodiversity. Or maybe one can find out how the problem of species loss could be solved easier, if for example development factors have a positive influence.

4. Research Hypotheses

Several studies suggest that modern humanity has a negative impact on biodiversity and that the negative impact fuels the species loss.[21] The question to solve is, if this impact is always negative, or if it becomes positive when countries develop economically. This study wants to show if there is a connection between economic growth, measured in GDP per head, and the α-index of the Species Area curve. There are different settings possible:

1. Linear negative correlation: Biodiversity is decreasing steadily as the countries become richer. In this case biodiversity is lost inevitably without any chance of improvement.
2. Quadratic negative correlation: Depending on the maximum biodiversity would rise first but as the country becomes richer it would fall again. And the biodiversity loss would accelerate as the country becomes richer.
3. Quadratic positive correlation: Biodiversity would be lost with lower GDP per head, but at some point the country would be rich enough to invest in biodiversity conservation and would be able to reverse parts of the losses or even the whole loss. This would be a U shape similarly to an EKC.
4. Cubed correlation: Here, it depends on the coefficients, if the relevant part of the function is rising, falling or both. This specification could also show a relationship looking like an EKC.

Which of these models is the most plausible one? For the linear model Dietz and Adger (2003) already showed, that it does not fit for deforestation. Intuitively one can see that

20 See Hobohm (2000) p. 18
21 see Wilson (1986) p. 10

some diversity would remain, even if humanity would grow very large. Diversity will not decrease to zero, so a linear connection is not convincing. Still Dietz and Adger claim, that biodiversity does not recover from losses, so they are not testing for a cubed model in their study.[22] But there are examples, that species do show up again, after they where lost, if they are protected effectively or the biosphere is cleaned. Best examples are wolves in Germany and salmons in the Rhine. Of course when a species is extinct on the whole globe like the Tasmanian Tiger it is not yet possible to revive it. But as long as the species still exists in the neighboring countries it can invade as soon as the habitat is restored. Especially for plants whose seeds are carried by the wind or animals this is a possibility. Although Wilson (1986) claims, that it can take centuries to restore a rainforest after it has been cut down.[23] Also, especially for islands there is evidence that a certain number of species is reached for its area. Even if parts of the latter become extinct, the number would recover over a long time period. This also applies to habitat islands.[24]
So a quadratic positive or cubed specification seems to be the most plausible options, even if the recovering of biodiversity would take very long.

5. Variables and Data Sources

In the following the different factors and their data source are introduced. There will also be given some intuition why they should have an influence on the α-indexes and if it is positive or negative.

a) Alpha Indexes

The α-indexes are taken from Hobohm (2000) who estimated an Species Area curve for plants for 99 regions worldwide.[25] For the regression he took data from Davis et al. (1986) and Davis et al. (1995) who gave detailed information about different sample regions in these countries. For some countries there is data in both publications. In these cases the author assumes, that Hobohm used the latest data available to calculate the alpha level, so that GDP per head and all other independent variables where also derived from year 1995.[26] In some cases Davis et al. give a range of plants existing in a country or only provide estimations how many plants may exist there.[27] This leads to a range of α-indexes from which the value closest to zero where taken for the regression.

b) GDP per Capita

Data for GDP where taken from the Penn World Tables.[28] It is converted in purchasing power parity in 2005 prices and derived from the growth rate of consumption share, government share, and investment share of the real GDP.[29]

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22 See Dietz and Adger (2003) p. 25 f.
23 Wilson (1986) p. 9
24 Wilson (1986) p. 6
25 See Hobohm (2000) p. 41
26 For detailed information about the data set see Appendix A
27 E.g. see Davis et al. (1986) p. 17, p. 181 and p. 186
28 Heston, A.; Summers, R.; Aten, B., Penn World Table Version 7.0, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, May 2011.
29 See Data Appendix for a Space-Time System of National Accounts: Penn World Table 6.1 (PWT 6.1)page 12.

GDP per capita is still one of the most frequently used indicators to measure the economic development of a country. Since there is a discrepancy between the development of GDP and the Human Development Index, as Hopkins (1991) already discovered[30], a second regression will be run for the HDI replacing GDP per head. But in order to test if there is a classical EKC correlation, the GDP per head will be used. This also provides comparability to other studies before. Anyhow on should take into account the critique of Stern (1998) that better median incomes should be taken instead of mean incomes.[31] Median incomes reflect the distribution of income in a better way which again should have an influence on environmental politics as mentioned above. Still the mean income seems to be a reasonable approximation for a country's development.

c) Human Development Index

The HDI was introduced by the first Human Development Report in 1990. Despite the Gross National Income in purchasing power parities it is taking the life expectancy, mean years of schooling and expected years of schooling into account.[32]

The HDI is regularly published by the United Nations Development Program and is available via internet.[33] As Hopkins (1991) wrote GDP per head does not show all dimensions of development. It is possible, that a country does not have a large economical growth but does improve its education system in the same period, which is the basis for future growth. Still it is assumed that development especially in education and the health sector should have a positive impact on the environment.[34]

Because of development being this multidimensional a second model is run to check if an EKC is also found for other development measures or if the EKC does only exist with respect to economic growth.

The model for the HDI can have the same specifications as mentioned for the GDP. Namely linear negative, linear positive, quadratic negative, quadratic positive or cubic.

As the GNI is partly congruent with the GDP the variables are not completely independent. But GNI is only one third of the HDI, so the problem will be relatively small. Because of the same reason, education and life expectancy will not be included in regressions with HDI, but will be used to check for robustness of the results.

d) Population Density

As in Davis et al. (1986) numbers of population and size of country were given, the population density was calculated from these data as persons per km². Data for 1995 where taken from the Penn World Table.[35] The population density should have a negative impact on biodiversity because of the fact, that more people on the same piece of land need more food and more space for living, which leaves less space for all plants being there in the first place. Also population growth is seen as one reason for growing solid

30 Hopkins (1991) Human Development Revisited: A New UNDP Report.
31 See Stern (1998) p. 183
32 See HDR Technical Notes p.1
33 Source of Data: http://hdr.undp.org.
34 See Hopkins (1991) p.1.
35 Heston, A.; Summers, R.; Aten, B., Penn World Table Version 7.0, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, May 2011.

waste, air and water pollution.[36]

e) Agricultural Sector

The share of the agricultural sector is taken as another proxy for the development of a country. Usually a developing country starts off with a growing agricultural sector and later industrializes the economy. The share of agriculture becomes smaller, the more industry and service sector are growing. The larger the agricultural sector is, the worse should plants diversity be.

f) Education

In this data set education is measured in mean years of schooling of adults over 25. The data was also collected from the UNDP.
Education should have a positive influence on biodiversity because the more people know about the impact they have on the ecosystem the more they try to avoid too much damage. Additionally education is part of the HDI. Thus, it will not be included in the model with HDI to avoid multicolinearities.

g) Life expectancy

Life expectancy could have a positive influence because people who expect to become old, might have an interest in an intact environment when they are old. It is also an indicator for development because a country with high life expectancy has a good health system and a relatively low mortality rate for children.

h) Precipitation

The average precipitation per year in the largest city of the country is used as a proxy for the climate in the country. The more humid the region is, the more plants should exist. Of course the data is not optimal, because several countries span over very different climate zones.

I) LIEC and EIEC – Legislative and Executive Index of Electoral Competitiveness[37]

The two indexes reflect parts of the political system in a country. In this case if legislative and executive powers are elected and if they are elected in free competition or not. It is assumed that in a competitive election the interest of the people is better reflected than in countries without or with worse electoral systems. A change in demand for environmental goods should be accompanied by a change in politics in a country with a high electoral index. Both indexes should have a positive impact on the α-index, because checks and balances are better established than in autocratic countries. Also small interest groups can be elected and do have political influence. As biodiversity is slow in reaction the average of

36 See Cropper, M. and Griffith, C. (1994) p. 250.
37 DPI (2010) The World Bank

the last six years before the observation (namely 1980-1985 or 1989-1994) were taken into account. The index is scaled from 1 to 7:

1 no legislature /no executives

2 unelected legislature /unelected executives

3 elected, one candidate

4 1 party but multiple candidates

5 multiple parties are legal but only one won seats

6 multiple parties did win seats but the largest party received more than 75% of the seats

7 largest party got less than 75% of the seats

(see Keefer, P. (2010) DPI2010 Database of Political Institutions: Changes and Variable Definitions p.15f)

The summary of all variables is shown in table 1

Variable	Obs	Mean	Std. Dev.	Min	Max
alphalow	97	-.025567	.3950474	-1.15	.91
GDPpercap	92	10045.22	10564.22	204.4	51038.49
population	96	4.67e+07	1.56e+08	54000	1.22e+09
countrysize	95	1203778	2601625	316	1.71e+07
popdens	95	95.25465	163.5466	.0248207	1202.532
edu	94	5.431915	2.986068	.1	12.1
agric	94	14.97809	12.29352	.34	52.74
HDI	74	591.8514	182.0796	178	889
Precip	93	998.8978	706.3023	25	3800
Lifeexp	93	64.40968	10.54658	40.1	79.9
LIECav	93	4.884624	1.966177	1	7
EIECav	93	4.584409	2.055462	2	7

Table 1: summary of variables

6. Model and Results for GDP

For GDP 3 different models were run:

Model 1:

$$alphalow = \beta_1 + \beta_2 GDP + \beta_5 HDI + \beta_6 agric + \beta_7 precip + \beta_8 LIECav + \beta_9 EIECav + \beta_{10} popdens + \varepsilon_1$$

Model 2:

$$alphalow = Model1 + \beta_3 GDP^2$$

Model 3:

$alphalow = Model1 + \beta_3 GDP^2 + \beta_4 GDP^3$

With $agric$ being the agricultural variable, $precip$ for precipitation and $popdens$ for population density, $LIECav$ and $EIECav$ are the averages of the legislature and executive indexes explained above and ε_1 is the error term.

Stern 1996 suggests that a test for heteroskedasticity should be run, to check if the variance of variables is constant.[38] The test was performed for all models and the H0 Hypothesis that the variance is constant could not be rejected. Therefore the variance is constant.

Table 2 shows the results for the 3 models.

Coefficient	*Model 1*	*Model 2*	*Model 3*
GDPpercap	-0.0000248***	-0.0000582***	-0.0000055
GDP²		0.000000000721**	-1.83E-009
GDP³			0.0000000000000333*
popdens	0.0000331	0.0000267	0.000014
agric	-0.0044006	-0.0062524	-0.0041945
HDI	0.0008776*	0.0013279***	0.0009888**
precip	0.0001991***	0.0013279***	0.000192***
LIECav	0.0659515*	0.0772359**	0.0848685**
EIECav	-0.0287551	-0.0219639	-0.0244648
cons	-0.5728937**	-0.6971615**	-0.7498559***
R²	0.5019	0.5386	0.5658
Number of Observations		73	

Table 2: Model 1-3

The stars behind the coefficients show the significance level of 1 percent (***), 5 percent (**) and 10 percent (*).

The first eye-catching result is that neither population density nor the percentage of the agricultural sector has a significant influence on plant diversity.

Also the Electoral Index for executives has no significant influence on the α-index. On the other hand the Legislative Index does have a significant positive influence in all three models. In line with the results from Torras and Boyce (1998) it seems that democratic structures play an important role in solving environmental problems. One explanation could be that small interest groups also do have an influence on the legislative when it is

38 Stern (1996) p. 1156

elected from plural candidates. The possible candidates want to gain more votes and therefore include more topics in their programs hoping that the interest groups can be convinced to vote for them. The other reason is, that in a relatively free electoral system checks and balances are working better. So corruption and fraud should be lower under a plural democracy with high LIEC and EIEC than under a dictatorship or a one-party-democracy.[39]

Also the result for precipitation is as predicted. It is in all cases positive and highly significant, which is consistent with the intention to use it as an approximation for climate. As will be seen this result is robust against all changes in the models described later in this text. The thesis that more precipitation leads to higher plant diversity is confirmed.

Not surprisingly the HDI has a significant influence, too. As the index is composed from GNI, life expectancy and education, this is consistent with the assumption above, that also other factors of development do have an influence on biodiversity.

For GDP the results are multidimensional. First one can see, that model 3 has the highest R^2, so this is the model that fits the data best out of the three. In this case the coefficient is weakly significant. Still the coefficient is positive and that would mean that the influence could have the form of an EKC. This result is supported by the numbers shown for model 2. Here GDP and GDP^2 are significant on a 5 percent and 1 percent level respectively. Because the squared term has a positive and the normal term has a negative influence, it also hints that an EKC exists for the α-index data.

To check if these results are robust against changes of the independent variables, HDI was first substituted by life expectancy and education. Because the results did not improve the explained scatter of the data, the results will not be reported in detail. Secondly population density was split up and population and country size were put in the regression. Table 3 shows the results for model 1a, 2a and 3a.

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39 see DPI 2010 p.19

Coefficient	Model 1a	Model 2a	Model 3a
GDPpercap	-0.0000244***	-0.0000568***	0.00000598
GDP²		0.000000000696**	-0.00000000233*
GDP³			0.0000000000000394**
popdens	0.0000329	0.0000405	0.0000346
population	1.80E-010	1.10E-010	1.48E-010
countrysize	7.23E-009	1.00E-008	1.53E-008
agric	-0.0045743	-0.0062647	-0.0038258
HDI	0.0008359*	0.0012733**	0.0008492*
precip	0.0001893***	0.0001783***	0.0001808***
LIECav	0.0681427**	0.077287**	0.0860362**
EIECav	-0.0295091	-0.0213007	-0.0236008
cons	-0.5659094**	-0.6880123**	-0.7469085***
R²	0.5143	0.5478	0.5839
Number of Observations		73	

Table 3: Model 1a-3a

As in models 1-3 only GDP, HDI, precipitation and the legislature index, of which the precipitation is the most robust one with a significance level of 1 percent. HDI and LIEC are again significant of varying levels. Focusing on the squared and cubic specifications of the model the legislature index is significant of a 5 percent level. HDI is significant at a 5 percent level in the squared model but only at a 10 percent level in the cubic model.

For the GDP the squared model shows a clear EKC correlation. And also for the cubic model the GDP^3 and the GDP^2 term are significant, although GDP^2 only at a 10 percent level. So the EKC relationship seems to be a robust phenomenon for the biodiversity data used.

Both estimated EKCs are plotted in figure one, where only the significant terms were used.

The point of interest is the minimum of the functions which indicates how large the economy must grow before the environment will recover again. For model 2a this point is reached at about 40804 $ GDP per capita. This corresponds with an α-index of -1.8469, a value which far exceeds Greenland and Spitsbergen with an α of -1.15. With about 39286 $ GDP per capita and an α-index of -1.9541 the function for model 3a is very similar.

Figure 1: Estimated EKCs

According to the data from 1986 and 1995 only Qatar has already reached the turning point. Taking the GDP data from 2009, only 13 out of 190 countries[40] have reached or passed the turning point. According to this, there will be a long term of biodiversity loss, when politics only count on environmental growth to avoid species loss. During this period of degradation the α-index level will become lower than the level of Greenland and Spitsbergen, the two coldest and least diverse territories Hobohm (2000) examined. Under these circumstances policies should not rely on growth as only action against loss of plant diversity. It would be better if one looked far a way to 'tunnel through' the EKC as Munasinghe (1999) called it. This means avoiding the minimum of the EKC by using politics to delink the environmental damage from growth, especially by learning from the countries that already have passed the minimum.[41] These countries may have developed effective measures and instruments to reduce the damage.

7. Results for HDI

Analogue to model 2a and 3a an HDI model was tested. It has the fromula: $alphalow = \beta_1 + \beta_2 HDI + \beta_3 HDI^2 + \beta_4 GDP + S + \varepsilon_1$

where

$S = \beta_5\, population + \beta_6\, countrysize + \beta_7\, popdens + \beta_8\, agric + \beta_9\, precip + \beta_{10}\, LIECav + \beta_{11}\, EIECav$

40 Data from Penn World Table 2010. The countries are: Australia, Bermuda, Brunei, Kuwait, Luxembourg, Macao, the Netherlands, Norway, Qatar, Singapore, Switzerland, United Arab Emirates and the United States of America.

41 Munasinghe (1999) p. 96

The results for the regression are shown in table 4.

Source	SS	df	MS
Model	5.7311166	10	.57311166
Residual	4.43301769	62	.071500285
Total	10.1641343	72	.141168532

Number of obs =	73
F(10, 62) =	8.02
Prob > F =	0.0000
R-squared =	0.5639
Adj R-squared =	0.4935
Root MSE =	.2674

alphalow	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
HDI	.0041595	.0013213	3.15	0.003	.0015182	.0068008
HDIsqrt	-3.42e-06	1.29e-06	-2.66	0.010	-5.99e-06	-8.44e-07
population	-7.68e-12	2.33e-10	-0.03	0.974	-4.73e-10	4.58e-10
countrysize	2.49e-08	1.87e-08	1.33	0.189	-1.26e-08	6.23e-08
popdens	.0000969	.0002002	0.48	0.630	-.0003032	.0004971
GDPpercap	-.0000146	6.23e-06	-2.34	0.023	-.000027	-2.11e-06
agric	-.0013816	.0046709	-0.30	0.768	-.0107185	.0079553
Precip	.000186	.0000473	3.93	0.000	.0000915	.0002805
LIECav	.0616144	.0323875	1.90	0.062	-.0031273	.126356
EIECav	-.0105563	.0327065	-0.32	0.748	-.0759355	.054823
_cons	-1.454182	.419595	-3.47	0.001	-2.29294	-.6154232

Table 4: HDI-model

As can be seen HDI and HDI^2 do have a significant influence on the alpha index. But the HDI^2 term is negative, so that the result is an inverted U-shaped curve.[42] This means, that growth in income is attended by an accelerating loss of plant diversity. This is surprising because the influence of HDI and GDP should at least have had the same sign, if they both should represent development of a country. This supports the thesis of Dinda (2004) that the EKC is a statistical artifact resulting from human behaviour, but does not show any causal chains.[43] But obviously it does only exist for the GDP measure and not for another measure of development. The HDI-model does not fit the data better, as can be seen in the lower R^2, so the EKC result for GDP^3 is still be seen as more valid.

8. Conclusion

According to the regressions made a classical EKC for vascular plant diversities α-index does exist. The research hypothesis of a positive quadratic or a cubic specification is found. Even in today ranges of GDP per head the turning points are quite high and the α-indexes are predicted so low, that policy makers should not rely on growth to solve the problem of biodiversity loss. Otherwise damages will occur, from which nature will take centuries to recover. In fact developing countries should try to learn from the few countries who managed to maintain or reestablish a high diversity level to avoid these damages.

42 A model with HDI^3 was tested, but did not result in any significant levels for any specification of HDI and had no higher R^2.

43 Dinda (2004) p. 432

The U-shaped influence of an alternative measure for GDP, the HDI, can not be confirmed. Here the HDI has accelerating negative influence on biodiversity.

Looking at the other influence factors, beside the climate in a region the political competitiveness has a significant and positive influence. This makes perfect sense, because one of the biggest issues regarding environmental problems is the internalization of externalities which can be solved by distribution of property rights or other regulations. So, next to economic growth political freedom could help to protect biodiversity.

Thus the next step would be exploring how potential shortcuts of the EKC could look like, to avoid the absolute minimum of the curve. In order to do so the countries that already have passed the minimum could be examined with respect to their political system and their strategy in environmental protection.

Country	alphalow	population	countrysize	Popdens	GDP per capita	Education	Agriculture (% of GDP)	Lifeexpectancy	HDI	Precipitation	LIECav	EIECav
Afghanistan	-0.1	14292000	636267	22.46	1009.53	1.20	13,93**	40.8	234	313	3.08	2
Albania	0.18	2985000	28748	103.83	3019.25	7.60	0.34	71.4		1250	3	3
Algeria	-0.33	2127200	2381745	0.89	5149.53	2.40	8.99	63.8	510	686	4	3
Angola	-0.06	8540000	1246700	6.85	2285.72	2,7*	14.38	40.8		1100	2.67	2.83
Argentinia	0.08	30094000	2777815	10.83	7719.12	7.40	7.8	70.6	687	1147	3	3.67
Australia	0.22	17975630.00	7692024	2.34	28866.94	11.80	3.41	78.1	889	1304	7	7
Austria	0.02	7489000	83853	89.31	24666.72	7.80	3.93	74	762	607	7	7
Bangladesh	0.16	98464000	143998	683.79	760.64	2.40	31.93	56.9	324	2400	4	4.17
Belgium	-0.09	9877000	30519	323.63	22773.39	8.50	2.27	74.8	777	810	7	7
bhutan	0.34	1388000	46620	29.77	1126.45	4,3*	43.83	49.3		1427	4	2
Bolivia	0.48	6200000	1098575	5.64	2637.80	5.30	18.33	55.7	527	800	5	2
Brazil	0.73	132648000	8511965	15.58	7826.58	3.20	11.15	64.4	575	2000	7	3
bulgaria	0.06	9182000	110912	82.79	6153.38	8.50	13.14	71.3	689	570	3.5	3
cameroon	0.28	9467000	475500	19.91	2575.13	2.80	22.36	52.9	418	1600	4	2.67
Canada	-0.43	25302000	9922387	2.55	26016.21	9.90	3.52	76.4	834	790	7	7
Cape Verde Is	-0.22	317000	4033	78.60	1546.46	2,7*	16.02	62.8			3.5	3.5
Chad	-0.55	4901000	1284000	3.82	746.87	2,7*	32.62	50		400	1	2
Chile	0	11878000	751626	15.80	4573.07	7.30	8.96	72	654	312.5	1	2
China	0.43	1215787460.00	9574033	126.99	2127.44	5.70	19.86	70.4	541	1500	3	3
Colombia	0.91	28110000	1138914	24.68	4292.82	4.80	17.45	67.6	568	3000	7	7
Congo	0.01	1695000	342000	4.96	2307.52	2,7*	18,17*	57.1	507	1375	3	2
Costa Rica	0.68	2534000	50899	49.78	7369.17	6.20	11.85	74.6	626	1867	7	7
Cuba	0.38	9966000	114524	87.02	10635.69	7.70	12.54	74.3	665	1250	3	3
Czeck Republ	-0.06	15588000	127870	121.91	na	10.50	4,18*	71.1		527	4	3
Denmark	-0.18	5141000	43075	119.35	25885.94	9.80	5.01	74.5	802	640	7	7
Djibuti	-0.51	354000	23000	15.39	3785.70	2,5*	10,39*	50.1		163	3.67	3
Ecuador	0.61	9090000	461477	19.70	5087.89	6.00	10,29*	66.1	614	1026	7	7
Egypt	-0.41	45657000	1000250	45.65	2525.34	3.00	19.98	59	461	25	6	6
Finland	-0.47	4859000	337032	14.42	21611.02	8.20	7.94	74.6	775	651	7	7
Former Sovie	0.13	148490270.00	17075400	8.70	8237.41	8.90	6.62	68.4		691	5.83	5
France	-0.01	54449000	549619	99.07	22720.71	6.40	4.57	75.5	742	650	7	7
Germany	-0.2	77872000	356921	218.18	23285.10	6.00	1.92	74.3	745	933	7	7
Ghana	0	13044000	238305	54.74	768.02	4.20	48.43	54.6	394	1500	3	3.67
Greece	0.22	9884000	131986	74.89	17159.26	7.30	4,18*	76	747	371	7	7
Greenland	-1.15	54000	2175600	0.02								
Guatemala	0.44	8165000	108888	74.99	4809.53	2.70	10,29*	59.6	437	2000	4	4.5
Hungary	-0.08	10786000	93032	115.94	11682.54	8.80	17.89	69.2	710	563	4	3
Iceland	-0.78	239000	102819	2.32	26422.73	7.90	11.89	77.2	782	801	7	7
india	0.3	920585000.00	3166414	290.73	1564.59	3.30	28.52	59.8	437	2168	5.67	6.83
Iraq	-0.16	15158000	438446	34.57	7082.57	2.10	10,39*	57.2		170	3.5	2
Ireland	-0.34	3555000	68895	51.60	14301.41	10.10	10.54	73.6	754	731	7	7
Israel	0.06	4216000	20705	203.62	16432.98	10.30	11,32**	75.2	785	500	7	7
Italy	0.13	56724000	251447	225.59	21976.64	6.60	4.66	75.5	735	944	7	7
jamaica	0.3	2290000	11425	200.44	6017.00	5.80	10,29*	71.1	611	3800	5.67	5.67
Japan	-0.01	125341350.00	377944	331.64	29967.95	10.40	2.09	79.9	850	1406	7	7
Kenya	0.11	19761000	582644	33.92	1087.20	3.40	32.59	59.5	438	1063	4.5	2.5
Kuwait	-0.82	1703000	24281	70.14	30696.47	5.30	0.61	71.5	715	108	3	2
Libya	-0.54	3471000	1759540	1.97	22952.51	2.90	17,43*	64.6		270	2	2
Madagaskar	0.4	9731000	594180	16.38	920.30	2,4*	35.14	49.3		1459	4	4

Appendix A

Country	alphalow	population	countrysize	Popdens	GDP per capita	Education	Agriculture (% of GDP)	Lifeexpectatancy	HDI	Precipitation	LIECav	EIECav
Malawi	0.09	6788000	94081	72.15	665.82	2.10	42.89	46.1	280	922	4	2
malaysian pe	0.32	20339000.00	330803	61.48	8671.86	7.60	13.66	71.1	600	2366	7	6
Mali	-0.55	7825000	1240142	6.31	684.61	0.50	40.29	42.2	182	878	4	3
Malta	0.24	380000	316	1202.53	10832.71	7.60	4.34	74.2	720	553	7	7
Mauritania	-0.69	1832000	1030700	1.78	1272.74	2.00	22.51	54.9	339	200	1	2
Mexico	0.45	77040000	1972546	39.06	8460.47	4.80	10.07	68.8	629	848	7	6.5
Mongolia	-0.43	1851000	1565000	1.18	2607.41	6.60	16.4	58.8	529	217	3	3
Morocco	-0.11	22848000	659970	34.62	2218.65	1.70	16.44	61.3	406	426	7	2
Namibia	-0.2	1507000	824293	1.83	3579.90	4.90	9.44	59.8	539	450	-999	0
Nepal	0.31	16107000	141414	113.90	811.81	1.20	51.71	51.1	285	1360	4	3.67
Netherlands	-0.18	14339551	41160	348.39	25370.74	9.70	4.27	76.5	806	760	7	7
New Caledoni	0.27	152000										
New Zealand	-0.28	3642180.00	270534	13.46	21371.96	11.90	7.44	76.9	861	1120	7	7
Nicaragua	0.21	3162000	148000	21.36	3257.51	3.60	10,29*	60.7	463	1147	2.67	2.83
Niger	-0.68	5940000	1186408	5.01	561.85	0.50	36.74	40.1	178	2800	1	2
Nigeria	-0.05	92037000	923850	99.62	1131.84	2,7*	18,17*	45.9		1507	5	5.33
Norway	-0.37	4140000	323895	12.78	31238.64	10.00	3.31	76	819	763	7	7
Oman	-0.52	1181000	271950	4.34	14048.94	2,5*	2.77	66		250	1	2
Pakistan	0.01	134185000.00	796095	168.55	2052.91	2.80	25.55	62	420	218	7	7
Panama	0.53	2134000	78513	27.18	5930.82	6.60	8.29	71.3	654	1500	4.5	4.5
philipines	0.36	72597430.00	299764	242.18	2073.89	7.50	22	66	586	1970	6	3
Poland	-0.2	37228000	312683	119.06	8352.86	8.30	4,18*	71		686	4	3
Portugal	0	10008000	91631	109.22	11523.35	5.60	14.8	73.2	670	753	7	7
Qatar	-0.7	291000	11437	25.44	51038.49	5.00	10,39*	72.7	728	75	1	2
Romania	-0.02	22048305	237500	92.83	7545.76	8.60	4,18*	69.6		595	4	3
Saudi Arabia	-0.33	10824000	2401554	4.51	15800.17	4.80	3.66	65.9	668	200	1	2
Senegal	-0.21	6352000	196722	32.29	1148.95	2.70	23.22	51	347	700	6	6
Somalia	-0.19	6400720.00	637657	10.04	489.99	2,7*	18,17*	44.7		350	3	3
South Afrika	0.58	31586000	1184827	26.66	5283.82	4.80	5.19	59.8	576	520	6	6
South Yemen	-0.54	2066000	287680	7.18	na	0.10	10,39*	53.6		350	3.5	3.5
Spain	0.02	38717000	504879	76.69	16575.81	5.50	6.18	76.4	717	456	7	7
Spitsbergen	-1.15											
Sri Lanka	0.11	18475880.00	65525	281.97	2308.81	7.20	23.76	69.1	604	2230	6	7
Sudan	-0.34	20945000	2505815	8.36	1050.62	1.10	33.54	51	273	140	3.5	3
Sweden	-0.39	8284000	449790	18.42	24715.37	9.50	4.77	76.8	796	539	7	7
Switzerland	0.09	6309000	41287	152.81	31759.55	9.70	3.28	76.7	817	1500	7	7
Taiwan	0.23	21214990.00	36188	586.24	18472.40	4,4*	6,10*			2000	3.67	3
tanzania	0.25	21710000	939762	23.10	611.64	3.20	18,17*	51.2		1148	2	3
Thailand	0.39	58855800.00	513120	114.70	6150.03	4.10	9.08	72.3	603	1498	6	7
Tunisia	-0.16	7042000	164148	42.90	3117.99	2.60	18.1	65.6	500	466	4.67	2
turkey	0.2	45358000	779452	58.19	6229.47	4.00	20.25	60.1	518	697	4	3.67
Uganda	0.14	15150000	236578	64.04	508.01	2.30	52.74	49.6	294	1300	6.17	6.17
United Kingd	-0.3	55624000	244754	227.26	21776.97	7.60	1.72	74.6	759	754	7	7
USA	0.27	235681000	9363132	25.17	29155.74	12.10	2.41	74.6	853	1201	7	7
Venezuela	0.61	17819000	912047	19.54	8218.03	5.10	6.3	69.7	627	916	7	7
vietnam	0.27	58307000	329566	176.92	837.54	4.40	40.17	61.1		2000	3	3
Zambia	-0.03	6445000	752617	8.56	1273.21	4.00	14	51.2	405	900	4	3
Zimbabwe	0.03	8461000	390310	21.68	204.40	4.00	22.67	61.5	425	1000	6	6.17

Data from 1995 (yellow)

* average data for the continents because country data was not available.

** avaerage data from 1995

Appendix B

Table Population Penn World table /Davis

	population according to Davis et al.	population according to Penn World Table
Afghanistan	14292000	13856100,00
Albania	2985000	3015440,00
Algeria	2127200	22642540,00
Angola	8540000	7748630,00
Argentinia	30094000	31144990,00
Australia	17975630.00	17975630,00
Austria	7489000	7568240,00
Bangladesh	98464000	101438050,00
Belgium	9877000	9861800,00
bhutan	1388000	546810,00
Bolivia	6200000	6041350,00
Brazil	132648000	140196280,00
bulgaria	9182000	8958770,00
cameroon	9467000	10530150,00
Canada	25302000	26203800,00
Cape Verde Islands	317000	324290,00
Chad	4901000	5214200,00
Chile	11878000	12261000,00
China	1215787460.00	1215787460,00
Colombia	28110000	30399710,00
Congo	1695000	2002140,00
Costa Rica	2534000	2723070,00
Cuba	9966000	10144380,00
Czeck Republic and	15588000	10308840,00
Denmark	5141000	5120530,00
Djibuti	354000	303760,00
Ecuador	9090000	9301080,00
Egypt	45657000	51593430,00
Finland	4859000	4917390,00
Former Soviet Union	148490270.00	148490270,00
France	54449000	56725300,00
Germany	77872000	77713490,00
Ghana	13044000	13781210,00
Greece	9884000	9951370,00
Greenland	54000	
Guatemala	8165000	7820000,00
Hungary	10786000	10630560,00
Iceland	239000	243000,00
india	920585000.00	920585000,00
Iraq	15158000	16247340,00
Ireland	3555000	3540500,00
Israel	4216000	4139680,00
Italy	56724000	56733830,00
jamaica	2290000	2322550,00
Japan	125341350.00	125341350,00
Kenya	19761000	20477120,00
Kuwait	1703000	1811490,00
Libya	3471000	3699540,00
Madagaskar	9731000	10327390,00
Malawi	6788000	7608480,00
malaysian peninsula	20339000.00	20339000,00
Mali	7825000	7494410,00
Malta	380000	346630,00
Mauritania	1832000	1763680,00
Mexico	77040000	78442430,00
Mongolia	1851000	1960800,00
Morocco	22848000	22457810,00
Namibia	1507000	1240350,00
Nepal	16107000	17002210,00
New Caledonia	152000	
New Zealand	3642180.00	3642180,00
Nicaragua	3162000	3263710,00
Niger	5940000	7039810,00
Nigeria	92037000	87092240,00
Norway	4140000	4166600,00
Oman	1181000	1537700,00
Pakistan	134185000.00	134185000,00
Panama	2134000	2212160,00
philipines	72597430.00	72597430,00
Poland	37228000	37504280,00
Portugal	10008000	9907410,00
Qatar	291000	387260,00
Romania	22048305	22599680,00
Saudi Arabia	10824000	13998300,00
Senegal	6352000	7004260,00
Somalia	6400720.00	6400720,00
South Afrika	31586000	35101380,00
South Yemen	2066000	10869580,00
Spain	38717000	38707560,00
Spitsbergen		
Sri Lanka	18475880.00	18475880,00
Sudan	20945000	23890620,00
Sweden	8284000	8384070,00
Switzerland	6309000	6603190,00
Taiwan	21214990.00	21214990,00
tanzania	21710000	22284170,00
Thailand	58855800.00	58855800,00
Tunisia	7042000	7547080,00
turkey	45358000	52127340,00
Uganda	15150000	14910720,00
United Kingdom	55624000	56796260,00
USA	235681000	240650760,00
Venezuela	17819000	17450160,00
vietnam	58307000	61439830,00
Zimbabwe	6445000	8876780,00

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