Economics Bulletin

Volume 35, Issue 1

Environmental Kuznets Curve and ecological footprint: A time series analysis.

Marie-Sophie Hervieux
LEMNA, University of Nantes

Olivier Darné
LEMNA, University of Nantes

Abstract

In this paper we examine the Environmental Kuznets Curve (EKC) hypothesis using the Ecological Footprint (EF), a more comprehensive indicator of environmental degradation, through a time-series analysis for seven Latin American countries covering the 1961-2007 period. We first test the EKC hypothesis from traditional linear and quadratic functions, with standard and logarithmic specifications. The EKC hypothesis is not supported for Latin American countries, suggesting that there is no improvement of environmental degradation when income increases. We find that most of the countries exhibit a positive linear relationship between the EF and GDP. Finally, we study the long-term relationship between the EF and GDP. The results show evidence of long-term relationship between income and EF for Brazil and Uruguay with quadratic and linear relationship, respectively, which improves the quality of the regressions.

Citation: Marie-Sophie Hervieux and Olivier Darné, (2015) "Environmental Kuznets Curve and ecological footprint: A time series analysis.", *Economics Bulletin*, Volume 35, Issue 1, pages 814-826
Contact: Marie-Sophie Hervieux - marie-sophie.hervieux@univ-nantes.fr, Olivier Darné - Olivier.darne@univ-nantes.fr.
Submitted: October 07, 2014. **Published:** March 30, 2015.

1. Introduction

Environmental issues are becoming a priority, even in political and economical fields. Authorities have to control actions which have an impact on our ecosystems, notably due to the current threats regarding climate change or natural disasters. They need to know how to act, and more precisely if economic growth allows improvement to the environment or damages it. It is thus useful to analyze the relationship between economic development and environmental quality via the Environmental Kuznets Curve (EKC) hypothesis.

The EKC hypothesis indicates that economic development initially damages environmental quality, but with further development the relationship appears to reverse and environmental degradation starts to reduce. This relationship produces an inverted U-shaped curve[1], where environmental degradation first rises and then falls with increasing economic development.[2] If this hypothesis is taken to be true, then the future environment may be assumed to be pollution-free whilst also possessing higher living standards.

Most studies of the EKC hypothesis use either a specific pollution measurement, such as Sulfur dioxide or nitrogen oxides, or a global pollution measurement, such as carbon dioxide (CO_2), as an environmental pressure indicator.[3] These particular pollutants are only a small part of environmental concerns on a global level. Consequently, the analysis performed in this paper tests the validity of the EKC using a much more comprehensive measurement of environmental degradation, the Ecological Footprint (EF). The choice of the EF as an aggregate measurement of environmental quality can be explained by the fact that: (i) it is a widely referenced measurement of sustainability (Nijkamp et al., 2004; Haberl et al., 2001); (ii) it has been adopted by a growing number of government authorities, agencies, and policy makers as a measurement of ecological performance (Wiedmann et al., 2006); and (iii) its limitations are well-known.

To the best of our knowledge, the existing literature on EKC hypothesis with the EF as an environmental pressure indicator contains only a few empirical studies. Rothman (1998), Bagliani, Bravo and Dalmazzone (2008), York, Rosa and Dietz (2004), and Boutaud, Gondran and Brodhag (2006) use cross-sectional data whereas Caviglia-Harris, Chambers and Kahn (2009) provide a panel data analysis. However, when studies use panel data techniques, particular attention must be paid to heterogeneity between countries because different countries could exhibit different turning points (if present) of the relationship between environmental quality and income (List and Gallet, 1999). As Stern (1996) suggested, a valid approach to overcome the heterogeneity issue between countries is to study the EKC hypothesis of individual countries. This approach allows researchers to model the relationship between a measurement of environmental degradation and income taking into account the specific historical experiences of each country. In this paper, we analyze the EKC hypothesis in a time-series dimension for seven Latin American coun-

[1]The idea of EKC came to the fore in 1991 with the Grossman and Krueger's study of the North American Free Trade Agreement (NAFTA) (Grossman and Krueger, 1991; Stern, 2004). Panayotou (1993) first coined the term EKC (see,also, Selden and Song, 1994). However, the EKC hypothesis became very important after 1991 for its potential and promise of finding a final solution to environmental degradation.

[2]The main explanation of this relationship would be the result of three different effects: scale effect, technological effect, and composition effect (Grossman and Krueger, 1991; Panayotou, 1997; De Bruyn et al., 1998; *inter alia*). There is another main explanation corresponding to the demand for environmental quality (Barrett and Graddy, 2000).

[3]See Lieb (2004), Stern (2004), Winslow (2005), and Miah et al. (2010), for a survey on the different studies of the EKC from various pollutants.

tries covering the 1961-2007 period. Latin America is highly concerned by environmental issues: environmental resources (renewable or not) are used in the economic production structure of these countries. Moreover, they are developing countries that are becoming more and more important on the international arena. Otherwise, they experienced early deindustrialization which may have an impact on their environment. Since there is no consensus on the functional forms of the EKC and the transformation of data, we examine the EKC hypothesis from linear and quadratic forms as well as with data in standard and logarithm forms.

Furthermore, previous studies using time series data lack a diagnostic analysis of the order of integration of the variable entering the long-term relationship as implied by the EKC, which could lead to spurious regressions (Granger and Newbold, 1974). If there is no cointegration in a regression among non-stationary variables, interpreting the results in the standard way is invalid. Cointegration testing is a powerful test of misspecification (Perman and Stern, 2003). Specifically, studies in a time-series dimension have mainly estimated the EKC relationship using error-correction models (ECM), but only with CO_2 as a proxy of environmental degradation (e.g., Jalil and Mahmud, 2009; Iwata et al., 2010; Fodha and Zaghdoud, 2010). In this paper, we use the cointegration tests of Johansen (1988, 1991) to examine the possible long-term relationship between the EF and GDP.

Our results support the EKC hypothesis only for Chile and Uruguay with the quadratic functional form. We also find that most of the countries exhibit a positive linear relationship between the EF and GDP. Otherwise results show evidence of long-term relationship between income and the EF for Brazil, Chile, and Uruguay.

This article is organized as follow: Section 2 presents the Ecological Footprint as environmental pressure indicator. Section 3 describes the EKC model and Section 4 briefly presents the methodology. Section 5 gives the empirical results. Finally, Section 6 concludes.

2. The Ecological Footprint as an environmental pressure indicator

The Ecological Footprint (EF) was introduced by Rees (1992) and further developed in Wackernagel and Rees (1996) to determine how the environmental damage associated to human consumption compares to the biosphere's regenerative capacity.[4] The EF estimates the amount of natural capital (measured in a biologically productive surface area) needed to support the resource demand and waste absorption requirements of a population and is expressed in global hectares or hectares of globally standardized bioproductivity (Wackernagel et al., 2004a, 2004b). In the basic calculation of the EF, consumption (categorized by food, services, transportation, consumer goods, and housing) is divided by the predetermined yield (biological productivity) by land type including cropland, pasture, forest, built-up land, fisheries, and energy land. The ability of these areas to supply ecological goods and services (i.e. the predetermined yield) depends on the biophysical characteristics of the land (such as soil type, slope, and climate) in addition to socio-economic choices (such as management decisions and technological inputs). This indicator had been created in terms of surface area, and thus is expressed as a single unit: global hectares (gha). A global hectare is an hectare which has a yield equal to the

[4]Biosphere's regenerative capacity is called Biocapacity (BC). If EF is greater than BC, we face an ecological deficit situation. Conversely, if EF is less than BC, we have an ecological reserve. In our sample, all countries have an ecological reserve but the EF can be still view as an environmental pressure indicator.

average yield of the world.[5]

More precisely calculation follows 3 steps:
First, the amount of consumed resources has to be identified. EF takes into account : (i) farm goods, (ii) fibers, (iii) wood, (iv) infrastructures, and (v) energy power expressed in physical unit.
Amounts of each kind of resource then are divided by the average yield of land and water area allowing to produce them in order to convert this data on area.

$$Considered\, areas = \frac{Amount\, of\, used\, resources}{National\, average\, yield\, of\, surface\, type\, X} \tag{1}$$

These hectares then have to been standardize by the use of a yield factor and an equivalence factor. Yield factor is needed because environment endowments (climate, relief, type of soil, etc.) are not the same in all countries, so land's productivity differs. By instance, a tonne of wheat does'nt need the same amount of area to be produced in country A than in country B. So it's essential to the comparison between countries.

$$Yield\, factor = \frac{National\, average\, yield\, of\, surface\, type\, X}{World\, average\, yield\, of\, surface\, type\, X} \tag{2}$$

In addition, the equivalence factor converting the surfaces in global hectare is useful and allows us to compare farmland to fishing areas by giving them an equal yield value. This factor also helps to express biocapacity with a surface which presents a yield similar to the ones usually observed. Indeed, a water area will not be as efficient as a farmland by instance.

$$Equivalence\, factor = \frac{World\, average\, yield\, of\, surface\, type\, X}{World\, average\, yield\, of\, all\, types\, of\, surface} \tag{3}$$

Fourth, we can add these surfaces, now expressed in a same unit in order to get the ecological footprint value.

However, the measurement is not all inclusive as it neglects atmospheric ozone levels, and does not account for pollutants that are difficult to convert to land or water ecosystem equivalents, such as methane and sulfur (Rees, 2000). The EF is an indicator centered only on the use of renewable resources. The assumptions that are made to convert this encompassing measurement into a single unit have lead to much of its criticism.

Despite these shortcomings, the EF represents a powerful indicator of the dynamics of renewable resource use, capturing a significant share of environmental pressure both on the input side and output side. This comprehensive view is particularly important in studying the EKC whose aim is describing a general relationship between economy and the environment (Bagliani et al., 2008). The EF is a widely referenced measurement of sustainability (Nijkamp et al., 2004; Haberl et al., 2001), and has been adopted by a growing number of government authorities, agencies, and policy makers as a measure of ecological performance (Wiedmann et al., 2006).

[5] Since 2003, the EF calculations are made by the Global Footprint Network (GFN), a non governmental organization created by Wackernagel and Burns. Data is available in the *Living Planet Reports*, published by the World Wildlife Fund (WWF). Note that the EF is a consumption-based indicator.

3. EKC model

Following standard practice, the EKC equations can be specified in traditional linear or quadratic form. We present here the quadratic form, given by:

$$EF_t = b_0 + b_1\, GDP_t + b_2\, GDP_t^2 + \epsilon_t \tag{4}$$

where EF_t stands for the per capita EF (g ha) during period t, GDP_t for the per capita GDP per period, b_0 denotes a constant term, and ϵ_t is the normally distributed error term.

If we consider only the linear functional form: if $b_1 > 0$, the relationship between GDP and EF is linearly increasing. Any increase in income results in a proportional increase in EF: the EF may worsen as per capita income increases. The relationship would be monotonically decreasing if $b_1 < 0$. In both cases, the link between environment and income only exists if b_1 is significant.

Concerning the quadratic form, i.e. the traditional one in EKC studies, the EKC hypothesis holds if $b_1 > 0$, $b_2 < 0$, and both are statistically significant. Therefore, a turning point and an inverse U-shaped relationship could exist. With these assumptions, there is a de-linking relationship between GDP and EF. In this case, environmental pressure increases at initial growth stages but at a decelerating rate, up to a threshold. However after this phase, growth allows improvements in the environmental state. Indeed, the two other effects are important enough to more than offset the scale effect. If $b_1 < 0$ and $b_2 > 0$, a U-shaped pattern is obtained, which is particularly bad for sustainable development assumptions. We note that they may only be an inflexion point and no turning point, so that, the relationship could be increasing or decreasing at different rates.[6]

4. Methodology

We first perform unit root tests to study the stationarity of the series: we apply ADF (Dickey and Fuller, 1981) and ADF-GLS (Elliott et al., 1996), taking into account either a constant or a constant and a trend. The results show that for each country both time series (EF and GDP) are integrated of order one, I(1), i.e. are non-stationary.[7] To avoid spurious regressions one of the solutions is to make the series stationary. However, differencing the series would prevent long-run analysis. In order to circumvent this problem, a number of techniques can be employed to test for the existence of the long-run equilibrium relationship (cointegration) among the time series variables. We thus perform Johansen tests (1988, 1991) to detect the number of long-run relationships.

In order to conduct cointegration tests, we first estimate a vector-autoregressive (VAR) model. The VAR(p) model is defined as

$$Y_t = A_1 Y_{t-1} + \cdots + A_p Y_{t-p} + \epsilon_t$$

where Y_t is a vector of non-stationary variables, and ϵ_t is innovation vector. The lag length, noted p, of the VAR(p) is determined from the criteria discussed in Lütkepohl

[6] A cubic form describes a relationship with two potential turning points, i.e. an N-shaped function. After an initial EKC-like phase, environmental pressure begins to increase again thereafter. We also tested for a cubic functional form but results were not pertinent.

[7] The results are available upon request.

(1991) to determine the lag length. Then, we implement the Johansen maximum likelihood procedure (Johansen, 1988, 1991). This approach consists in estimating a Vector Error Correction Model (VECM) by maximum likelihood, under various assumptions about the trend or intercept parameters and the number r of cointegrating vectors, then conducting likelihood ratio tests. We re-write a p-dimensional VECM as follows

$$\Delta Y_t = \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \Pi Y_{t-1} + \epsilon_t \tag{5}$$

where Δ is a difference operator, $\Pi = \sum_{i=1}^{p} A_i - Im$, the matrices $\Gamma_i = -\sum_{j=i+1}^{p} A_j$ contain information on the short-run adjustment coefficients of the lagged differenced variables, the expression ΠY_{t-1} indicates the error correction term, i.e. it includes the long-run relationships between the time series.

Johansen (1988, 1991) proposes to use the trace test[8] which is based on the log-likelihood ratio

$$\mathrm{LR}(r|k) \quad = \quad -T \sum_{i=r+1}^{k} \ln(1-\lambda_i)$$

where λ_i is the eigenvalue ranked at the i order, k is the number of endogenous variables, and $r = k-1, \ldots, 1, 0$. This LR statistic tests the null hypothesis of r cointegrating relations against the alternative of k cointegrating relations, where k is the number of endogenous variables, for $r = 0, 1, \ldots, k-1$.

5. Empirical Results

We consider annual time series data for per capita Ecological Footprint (EF) and per capita Gross Domestic Product (GDP) for seven Latin American countries covering the period 1961-2007. Our analysis focuses on Argentina, Brazil, Chile, Colombia, Paraguay, Peru and Uruguay. The EF data (consumption side) comes from the Global Footprint Network (GFN).[9] Per capita GDP data, expressed in constant US$ prices for the year 2000, has been obtained from the World Bank. Table 1 displays the shares in percentage of EF components (in mean).

Descriptive statistics are given in Table 2. For the per capita EF, Peru exhibits the lower mean (1.91) while Uruguay displays the higher level (5.90), suggesting an important degradation of environment compared to the others Latin American countries. Concurrently, per capita GDP belongs on average to the interval 1166.26 (Paraguay) and 6826.22 (Argentina).

We estimate two types of EKC models - linear and quadratic in standard or logarithm form - from OLS: (1) baseline EKC models on series in first differences (i.e. a short-run relationship); and (2) EKC relationship using error-correction models (ECM) (i.e. short-run and long-run relationships), if a long-run relationship exists.

Table 3 displays the results of the EKC estimations for the data in level form. The EKC hypothesis is only supported for Chile and Uruguay with the quadratic functional

[8]Based on simulation experiences, Lutkepohl et al. (2001) show that the trace test displays better properties than the maximum eigenvalue test.

[9]Global Footprint Network, 2010. National Footprint Accounts, 2010 Edition. Available online at http://www.footprintnetwork.org.

form. The statistically significant negative sign of GDP^2 confirms the delinking of EF and income at high income levels. For Chile, the turning point of income turns out to be US$ 6199.30 compared to the highest value in our sample of US$ 6078.40: it does not belong to the sample, the relationship could more likely be linearly increasing. However, for Uruguay, the turning point is reached for an income around US$ 6676 which belongs to the sample. Furthermore, we find that most of the countries exhibit a positive linear relationship between EF and GDP, except for Argentina and Uruguay, showing that any increase in income results in an increase in environmental degradation, with no hope of a decreasing phase.

Table 4 displays the results of EKC estimations for the data in logarithmic form. We do not find an inverted U-shaped relationship, showing that the transformation of the data can bias the results. We find that the linear relationship is statistically significant and positive for all the countries, except for Argentina. This result confirms the assumption of a monotone linear increasing relationship between GDP and EF. Furthermore, Brazil displays a quadratic relationship but not with the expected signs, i.e. an U-shaped relationship, implying that, environmental degradation first falls and then rises with increasing economic development. The turning point is reached for US$ 1635.98 corresponding to the per capita income of 1967-1968.[10] Note that for this country the $\overline{R}^2$ is higher than from the linear relationship.

Once a long-run relationship has been established from the Johansen's cointegration tests,[11] an error-correction model can be estimated for the EKC hypothesis from the following regression (with a linear, quadratic or cubic form):

$$EF_t = b_0 + b_1 GDP_t + b_2 GDP_t^2 + b_3 EC_{t-1} + \epsilon_t \tag{6}$$

The results of the ECM then allow measuring the adjustment speed required to adjust to long-run values after a short-term shock from the error-correction (EC) coefficient. Table 5 displays the estimation results of the ECMs, when a cointegration relationship has been detected, for both series in level and logarithmic forms. The results do not support the EKC hypothesis, implying that there is no improvement of environmental degradation for Latin American countries when income increases. However, we find long-run relationship between GDP and EF for Brazil, Chile[12] and Uruguay from data in both forms, suggesting the existence of a long-run equilibrium between EF and GDP: there is an error correction mechanism, i.e., in the long run, the differences between EF and GDP tend to compensate, variables move in a same way. For example, the error-correction coefficient of -0.32 for Uruguay, suggests that 32% movement backs towards equilibrium following a shock to the model, one time period later. All the error-correction coefficients (EC_{t-1}) are significatively negative.

Note that introducing the error correction term improves the quality of the regression with better in-sample criteria ($\overline{R}^2$, Log-Likelihood (LL), Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC)) and thus the fit of the model, showing the importance of taking this type of long-run relationship into account. For Brazil, the $\overline{R}^2 = 0.27$ from the quadratic relationship (in logarithmic form) whereas $\overline{R}^2 = 0.45$ from the quadratic relationship by adding the error-correction coefficient.

[10] Turning point is very soon in our sample, implying that relationship seems to be increasing thereafter. So relationship looks like an increasing one.

[11] Results are available on request.

[12] For Chile, we do not find short-term relationship between GDP and EF.

More interestingly, the results show short- and long-run relationships for several countries. Uruguay exhibits a positive linear relationship from data in both forms. Brazil displays an U-shaped relationship from data in logarithmic form, with a turning point reached for US$ 2463 which is an income reached in 1973 without any decrease in EF.

6. Conclusion

In this paper we examined the Environmental Kuznets Curve (EKC) hypothesis using the Ecological Footprint (EF), a more comprehensive indicator of environmental degradation, in a time-series dimension for seven Latin American countries covering the 1961-2007 period. We first tested the EKC hypothesis from traditional linear, quadratic and cubic functions, in standard and logarithmic specifications. The EKC hypothesis is not supported for Latin American countries, suggesting that there is no improvement of environmental degradation when income increases. We found that most of the countries exhibit a positive linear relationship between EF and GDP. Finally, we studied the long-run relationship between EF and GDP. The results showed evidence of long-run relationship between income and EF for Brazil and Uruguay with quadratic and linear relationship, respectively, which improves the quality of the regressions. Governments could expect benefits from environmental policies in a long term horizon. Indeed, there could be long run economic and ecological health gains if growth is planned properly. Degradation may be immediate but the health of the ecosystem is a long term process.[13]

To conclude, environmental policies are central: growth would appear to be not enough to improve environmental condition even when growth becomes cleaner. Indeed, we have chosen a consumption-based approach in order to capture the potential delocalization effects. Even if developed countries mainly produce services which are not as polluting as industrial goods, the consumption behavior of their inhabitants haven't changed. As a result, the level of demand of developed countries for polluting goods is still increasing. In these conditions, there is no hope of a turning point for the relationship between economic growth and the ecological footprint in Latin American countries.[14] Nevertheless, we will try in a forthcoming work to add several variables in order to analyze more precisely the EF-GDP relationship and to work both on consumption and production sides.

References

Bagliani, M., Bravo, G., Dalmazzone, S. (2008) "A consumption-based approach to environmental Kuznets curves using the ecological footprint indicator" *Ecological Economics* 65, 650-651.

Barrett, S., Graddy, K. (2000) "Freedom, growth, and the environment" *Environment and Development Economics* 5, 433-456.

Boutaud, A., Gondran, N., Brodhag, C. (2004) "Local environmental quality versus (global) ecological carrying capacity: what might alternative aggregated indicators bring

[13]The authors thank the anonymous referee for this comment.

[14]We have to pay attention to not generalize these specific results. Indeed, according to meta-analysises published in EKC field (see Cavlovic et al., 2000; and Hui et al., 2007) results are very sensitive to data, methodologies, and environmental pressure indicators.

to the debates about Environmental Kunzites Curves and sustainable development" *International Journal of Sustainable Development* 9, 297-310.

Caviglia-Harris, J., Chambers, D., Kahn, J. (2009) "Taking the "U" out of Kuznets. A comprehensive analysis of the EKC and environmental degradation" *Ecological Economics* 4, 1149-1159.

Cavlovic, T. A., Baker, K. H., Berrens, R. P., Gawande, K. (2000) "A meta-analysis of environmental Kuznets curve studies" *Agricultural and Resource Economics Review* 29, 32-42.

De Bruyn, S.M., Van den Bergh, J.C.J.M., Opschoor, J.B. (1998) "Economic growth and emissions: Reconsidering the empirical basis of Environmental Kuznets Curves" *Ecological Economics* 25, 161-175.

Dickey, D.A., Fuller, W.A. (1981) "Likelihood ratio statistics for autoregressive time series with unit root" *Econometrica* 49, 1057-1072.

Elliott, G., Rothenberg, T.J., Stock, J.H. (1996) "Efficient tests for an autoregressive unit root" *Econometrica* 64, 813-836.

Fodha, M., Zaghdoud, O. (2010) "Economic growth and pollutant emissions in Tunisia: an empirical analysis of the Environmental Kuznets Curve" *Energy Policy* 38, 1150-1156.

Granger, C.W.J., Newbold, P. (1974) "Spurious regressions in econometrics" *Journal of Econometrics* 2, 111-120.

Grossman, G.M., Krueger, A.B. (1991) "Environmental impacts of a North American Free Trade Agreement" NBER Working Paper number 3914, .

Grossman, G.M., Krueger, A.B. (1995) "Economic Growth and the Environment" *Quaterly Journal of Economics* 110, 353-77.

Haberl, H., Erb, K-H., Krausmann, F. (2001) "How to calculate and interpret ecological footprints for long periods of time: The case of Austria 1926-1995" *Ecological Economics* 38, 25-45.

Hui, L., Grijalva, T., Berrens, R.P. (2007) "Economic growth and environmental quality: a meta-analysis of environmental Kuznets curve studies" *Economics Bulletin* 17, 1-11.

Iwata, H., Okada, K., Samreth, S. (2010) "Empirical study on the environmental curve for CO_2 in France: The role of nuclear energy" *Energy Policy* 38, 4057-4063.

Jalil, A., Mahmud, S.F. (2009) "Environmental Kuznets Curve for CO_2 emissions: A cointegration analysis for China" *Energy Policy* 37, 5167-5172.

Johansen, S. (1988) "Statistical analysis of cointegration vectors" *Journal of Economic Dynamics and Control* 12, 231-54.

Johansen, S. (1991) "Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models" *Econometrica* 59, 1551-1580.

Lieb, C.M. (2004) "The Environmental Kuznets Curve and flow versus stock pollution: The neglect of future damages" *Environmental and Resource Economics* 29, 483-506.

List, J.A., Gallet, C.A. (1999) "The Environmental Kuznets Curve: Does one size fit all?" *Ecological Economics* 31, 409-423.

Lütkepohl, H. (1991). "Introduction to Multiple Time Series" Springer-Verlag, New York.

Lütkepohl, H., Saikkonen, P., Trenkler, C. (2001) "Maximum eigenvalue versus trace test for the cointegrating rank of a VAR process" *Econometrics Journal* 4, 287-310.

Miah, M.D., Rashid, H.A., Shin, M.Y. (2010) "Global observation of EKC hypothesis for CO_2, SO_x and NO_x emission: A policy understanding for climate change mitigation in Bangladesh" *Energy Policy* 38, 4643-4651.

Nijkamp, P., Rossi, E., Vindigni, G. (2004) " Ecological footprints in plural: A meta-analytic comparison of empirical results" *Regional Studies* 38, 747-765.

Panayotou, T. (1993) "The environment in Southeast Asia: Problems and policies" *Environmental Science and Technology* 27, 2270-2274.

Panayotou, T. (1997) "Demystifying the Environmental Kuznets Curve: turning a black box into a policy tool" *Environment and Development Economics* 2, 465-484.

Perman, R., Stern, D.I. (2003) "Evidence from panel unit root and cointegration tests that the Environmental Kuznets Curve does not exist" *The Australian Journal of Agricultural and Resource Economics* 47, 325-347.

Rees, W.E. (1992) "Ecological footprints and appropriated carrying capacity: what urban economics leaves out" *Environment and Urbanisation* 4, 121-130.

Rees, W.E. (2000) "Eco-footprint analysis: merit and brickbats" *Ecological Economics* 32, 371-374.

Rothman, D.S. (1998) "Environmental Kuznets Curves - real progress or passing the buck? A case for consumption approaches" *Ecological Economics* 25, 177-194.

Selden, T.M., Song, D. (1994) "Environmental quality and development: Is there a Kuznets Curve for air pollution emissions?" *Journal of Environmental Economics and Management* 27, 147-162.

Stern, D.I. (1996) "Progress on the Environmental Kuznets Curve? The Australian national university, center for resource and environmental studies" Ecological Economics Program, Working Papers in Ecological Economics, Number 9601 December 1996.

Stern, D.I. (2004) "The rise and fall of the Environmental Kuznets Curve" *World Development* 32, 1419-1439.

Torras, M., Boyce, J.K. (1998) "Income, inequality, and pollution: A reassessment of the Environmental Kuznets Curve" *Ecological Economics* 25, 147-160.

Wackernagel, M., Rees, W., Testemale, P. (1996) "Our ecological footprint: Reducing human impact on the earth", The New Catalyst Bioregional Series.

Wackernagel, M., Monfreda, C., Schulz, N.B., Erb, K. H., Haberl, H., Krausmann, F. (2004a) "Calculating national and global ecological footprint time series: resolving conceptual challenges" *Land use policy* 21, 271-278.

Wackernagel, Mathis, Monfreda, Chad, Erb, Karl-Heinz, Haberl, Helmut, Schulz, Niels B. (2004b) "Ecological footprint time series of Austria, the Philippines and South Korea for 1961-1999: comparing the conventional approach to an "actual land area" approach" *Land Use Policy* 21, 261-269.

Wiedmann, T., Minx, J., Barrett, J., Wackernagel, M. (2006) "Allocating ecological footprints to final consumption categories with input-output analysis" *Ecological Economics* 56, 28-48.

Winslow, M. (2005) "The Environmental Kuznets Curve revisited once again" *Forum for Social Economics* 35, 1-18.

York, R., Rosa, E.A., Dietz, T. (2004) "The ecological footprint intensity of national economies" *Journal of Industrial Ecology* 8, 139-154.

Table 1: Shares in % of EF components (means)

Country	Total EF	Cropland	Grazing land	Forest land	Fishing ground	Carbon	Built up land
Argentina	3.56	36.93	33.08	5.85	2.70	18.21	3.23
Brazil	2.85	28.67	36.34	20.82	1.95	9.33	2.88
Chile	2.38	31.39	18.07	23.46	7.82	16.62	2.65
Colombia	2.14	22.20	47.86	8.51	2.00	15.19	4.24
Paraguay	3.84	19.96	51.52	21.17	0.16	4.65	2.55
Peru	1.91	32.56	35.56	10.33	5.89	10.84	4.82
Uruguay	5.90	10.58	70.85	8.55	1.86	6.82	1.34

Table 2: Descriptive Statistics

Country	Variable	Mean	Min	Max	Std. Dev	Skewness	Excess Kurtosis
Argentina	EF	3.556	2.361	5.133	0.838	0.154	-1.442**
	GDP	6826.22	4956.22	9388.69	902.976	0.302	0.336
Brazil	EF	2.845	2.584	3.145	0.137	-0.252	-0.590
	GDP	3024.68	1548.13	4297.74	818.448	-0.761**	-0.763
Chile	EF	2.381	1.573	3.325	0.459	0.276	-0.950
	GDP	3164.63	1867.61	6078.40	1315.18	0.830**	-0.814
Colombia	EF	2.142	1.834	2.356	0.150	-0.612*	-0.624
	GDP	2050.80	1214.20	3083.13	515.685	-0.068	-1.066
Paraguay	EF	3.838	2.956	4.672	0.346	-0.554	0.427
	GDP	1166.26	682.186	1488.95	291.558	-0.605*	-1.329*
Peru	EF	1.908	1.392	2.855	0.496	0.857**	-0.822
	GDP	2073.89	627.87	2725.82	229.079	0.170	0.332
Uruguay	EF	5.902	4.798	7.102	0.643	-0.024	-0.993
	GDP	5333.10	4009.72	7759.28	1083.38	0.527	-0.952

Notes: *, ** and *** mean significant at 10% , 5% and 1% level, respectively.

Table 3: Results of OLS estimations (data in level form).

Country	Function	Intercept	GDP_a	$GDP^2{}_b$	R^2	LL	AIC	BIC	Results	Turning point
Argentina	Linear	-0.0618 (-1.226)	0.776 (0.624)		0.01	-13,813	31.63	35.28	No	
	Quadratic	-0.063 (-1.234)	-1.662 (-0.174)	0.175 (0.258)	0.01	-13.778	33.56	39.04	No	
Brazil	Linear	-0.024^{*} (-1.695)	4.562^{***} (3.958)		0.26	48.658	-93.32	-89.66	Increasing	
	Quadratic	-0.023 (-1.553)	0.239 (0.047)	0.689 (0.864)	0.27	49.054	-92.11	-86.62	No	
Chile	Linear	-0.051 (-1.407)	7.979^{***} (3.586)		0.23	9.400	-14.80	-11.14	Increasing	
	Quadratic	-0.037 (-1.038)	17.995^{***} (3.335)	-1.45^{**} (-2.024)	0.29	11.493	-16.99	-11.50	Inverted U-shaped	$6199.30
Colombia	Linear	-0.037^{***} (-3.622)	6.443^{***} (4.050)		0.27	70.925	-137.85	-134.19	Increasing	
	Quadratic	-0.041^{***} (-3.817)	14.326^{**} (2.084)	-1.566 (-1.178)	0.29	71.656	-137.31	-131.82	No	
Paraguay	Linear	-0.045 (-1.554)	14.217^{**} (2.344)		0.11	13.615	-23.23	-19.57	Increasing	
	Quadratic	-0.047 (-1.492)	22.655 (0.516)	-3.267 (-0.194)	0.11	13.636	-21.27	-15.78	No	
Peru	Linear	-0.031 (-1.548)	3.317^{*} (1.773)		0.07	28.059	-52.12	-48.46	Increasing	
	Quadratic	-0.030 (-1.484)	11.233 (0.642)	-1.871 (-0.455)	0.07	28.170	-50.34	-44.85	No	
Uruguay	Linear	-0.063 (-1.050)	3.621 (1.578)		0.05	-21.254	46.51	50.17	No	
	Quadratic	-0.060 (-1.034)	31.340^{**} (2.3655)	-2.347^{**} (-2.122)	0.14	-18.964	43.93	49.41	Inverted U-shaped	$6675.7

Notes: *, ** and *** mean significant at 10% , 5% and 1% level, respectively. $_a$ values are multiplied by 10^4. $_b$ values are multiplied by 10^7. The t-stat are given in parentheses. $EF_t = b_0 + b_1 GDP_t + b_2 GDP_t^2 + \epsilon_t$. "No" means no relationship between GDP and EF. LL means log-likelihood, AIC and BIC are Akaike and Schwarz criterion respectively.

Table 4: Results of OLS estimations (data in logarithmic form).

Country	Function	Intercept	GDP	GDP^2	R^2	*LL*	AIC	BIC	Results	Turning Inflection point
Argentina	Linear	-0.018 (-1.197)	0.247 (0.994)		0.02	42.360	-80.72	-77.06	No	
	Quadratic	-0.018 (-1.221)	-6.420 (-0.383)	0.379 (0.398)	0.03	42.445	-78.90	-73.40	No	
Brazil	Linear	-0.008 (-1.471)	0.399^{***} (3.291)		0.20	95.012	-186.02	-182.37	Increasing	
	Quadratic	-0.007 (-1.394)	-5.920^{*} (-1.983)	0.400^{**} (2.118)	0.27	97.295	-188.58	-183.10	U-shaped	$1635.98
Chile	Linear	-0.022 (-1.499)	1.166^{***} (4.349)		0.30	48.627	-93.25	-89.60	Increasing	
	Quadratic	-0.017 (-1.056)	6.485 (0.976)	-0.339 (-0.801)	0.31	48.968	-91.94	-86.45	No	
Colombia	Linear	-0.020^{***} (-3.909)	0.747^{***} (4.248)		0.29	104.970	-205.94	-202.28	Increasing	
	Quadratic	-0.020^{***} (-3.713)	-1.384 (-0.369)	0.139 (0.568)	0.30	105.142	-204.28	-198.80	No	
Paraguay	Linear	-0.013^{*} (-1.696)	0.454^{**} (2.303)		0.12	75.360	-146.72	-143.06	Increasing	
	Quadratic	-0.014 (-1.641)	1.488 (0.230)	-0.073 (-0.160)	0.11	75.374	-144.75	-139.26	No	
Peru	Linear	-0.017 (-1.544)	0.385^{*} (1.970)		0.08	59.774	-115.55	-111.89	Increasing	
	Quadratic	-0.015 (-1.494)	4.313 (0.305)	-0.257 (-0.278)	0.08	59.816	-113.63	-108.14	No	
Uruguay	Linear	-0.011 (-1.142)	0.409^{*} (1.898)		0.08	61.375	-118.75	-115.09	Increasing	
	Quadratic	-0.010 (-1.049)	17.427 (1.660)	-0.988 (-1.621)	0.13	62.739	-119.48	-113.99	No	

Notes: *, ** and *** mean significant at 10% , 5% and 1% level, respectively. The t-stat are given in parentheses. $ln(EF_t) = b_0 + b_1 ln(GDP_t) + b_2 ln(GDP_t)^2 + \epsilon_t$. "No" means no relationship between GDP and EF. LL means log-likelihood, AIC and BIC are Akaike and Schwarz criterion respectively.

Table 5: Results of long run OLS estimations.

Country	Function	Intercept	GDP	GDP^2	EC$_{t-1}$	R^2	*LL*	AIC	BIC	Results	Turning/ Inflection point
Data in level form											
Brazil	Quadratic	-0.019 (-1.491)	-10.230^{*} (-1.963)	1.94^{**} (2.539)	-0.530^{***} (-3.880)	0.47	56.099	-104.20	-96.88	U-shaped	\$2636.598
Uruguay	Linear	-0.029 (-0.532)	3.801^{*} (1.853)		-0.328^{***} (-3.480)	0.26	-21.254	37.09	42.58	Increasing	
Data in log form											
Brazil	Quadratic	-0.007 (-1.605)	-8.730^{***} (-3.174)	0.559^{***} (3.236)	-0.483^{***} (-3.616)	0.45	103.528	-199.06	-191.74	U-shaped	\$2462.67
Uruguay	Linear	-0.005 (-0.534)	0.416^{**} (2.158)		-0.312^{***} (-3.441)	0.27	66.969	-127.94	122.45	Increasing	
	Quadratic	-0.005 (-0.572)	13.771 (1.452)	-0.776 (-1.411)	-0.328^{***} (-3.379)	0.31	68.270	-128.54	-121.22	No	

Notes: *, ** and *** mean significant at 10% , 5% and 1% level, respectively, for the data in level form. GDP and GDP^2 values are multiplied by 10^4 and 10^7, respectively. The t-stat are given in parentheses.$EF_t = b_0 + b_1 GDP_t + b_2 GDP_t^2 + b_3 EC_{t-1} + \epsilon_t$, $ln(EF_t) = b_0 + b_1 ln(GDP_t) + b_2 ln(GDP_t)^2 + b_3 EC_{t-1} + \epsilon_t$
where EC_{t-1} is an error-correction term between EF and GDP. "No" means no relationship between GDP and EF. LL means log-likelihood, AIC and BIC are Akaike and Schwarz criterion respectively.