Production and consumption-based approaches for the Environmental Kuznets Curve in Latin America using Ecological Footprint.

Marie Sophie HERVIEUX[*]
LEMNA, University of Nantes

Olivier DARNÉ
LEMNA, University of Nantes

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[*] Corresponding author: LEMNA, University of Nantes, IEMN–IAE, Chemin de la Censive du Tertre, BP 52231, 44322 Nantes, France. +(33)02 40 14 17 31. Email: marie-sophie.hervieux@univ-nantes.fr.

Abstract

In this paper we examine the Environmental Kuznets Curve (EKC) hypothesis using the Ecological Footprint (EF), a more comprehensive indicator of environmental degradation, for five Latin American countries covering the 1971-2007 period. We test the EKC hypothesis using a traditional quadratic function from both the supply and consumption-side, adding several explicative variables: urbanization, petrol price and industrialization for supply-side; biocapacity, life expectancy and energy use for consumption-side. We perform an ARDL modeling in order to study both short and long-run periods. We find that there is no stable relationship between environment and economic development in the long-run. For the short-run analysis, the EKC hypothesis is supported for no one, we rather find an increasing relationship between growth and environment. Results for explicative variables are mixed: For production-side approach, industrialization appears to have a positive impact on EF for Chile. For consumption-side approach, we find that energy use seems to have a positive impact on EF for Argentina and Colombia whereas biocapacity and life expectancy have a positive and negative impact, respectively, on EF for Paraguay.

Keywords: Environmental Kuznets Curve; Ecological Footprint; ARDL.

JEL Classification: Q0; Q01; C32.

1 Introduction

What's behind the growth/environment relationship? Being able to understand the mechanisms affecting the environment while keeping the maximum rate of growth is the most important challenge of the 21st century. The income/environment relationship is theorized by the Environmental Kuznets Curve (EKC). The EKC assumes that economic development initially damages environmental quality, but the relationship appears to reverse with further development and environmental degradation starts to reduce. This relationship produces an inverted U-shaped curve, where environmental degradation first rises and then falls with increasing economic development. The literature in the field of EKC has been abundant since the initial work of Grossman and Krueger (1991). For a survey on EKC see Borghesi (1999), Dinda (2004), Stern (2004), Nourry (2007), and Bo (2011).

A majority of studies on the EKC hypothesis use either a specific pollution measurement, such as SO_x (Shafik and Bandyopadhyay, 1992; Selden and Song, 1994; Egli, 2002; Begun and Eicher, 2007; *inter alia*) or NO_x (Cole, Rayner and Bates, 1997; List and Gallet, 1999; Egli, 2001; *inter alia*), or a global pollution measurement, such as CO_2 (Shafik, 1994; Coondoo and Dinda, 2002; Jalil and Mahmud, 2009; Iwata, Okada and Samreth, 2010; *inter alia*) as environmental pressure indicator. There are also a number studies using others environmental pressure indicator, such as deforestation (Cropper and Griffiths, 1994; Koop and Tole, 1999;2001; Mills Busa, 2013; *inter alia*), water (Shafik, 1994; Grossman and Krueger, 1995; Gergel et al., 2004; Paudel et al., 2005; *inter alia*) or biodiversity (Dietz and Atger, 2003; Pallab et al., 2006; Mills and Waite, 2009; *inter alia*).

We choose to study Ecological Footprint (EF) as an environmental indicator as it is a much more comprehensive measurement of environmental degradation than any specific pollution measurement. It's an aggregate measurement of environmental quality (Nijkamp et al., 2004; Haberl et al., 2001), adopted by a growing number of government authorities, agencies, and policy makers as a measurement of ecological performance (Wiedmann et al., 2006).

Any environmental impact is often attributed to the production side of the economy and in particular the industrial sector (intensive pollution), however, studying the consumption side has also many advantages: notably that it avoids the bias of pollution havens (Rothman, 1998; Meunié, 2004; Aldy, 2005; Bagliani et al., 2008). Therefore, we use EF from both consumption and production-based approaches. Moreover, like Panayotou (1997), we feel that the EKC is something of a "black box" and, in fact is in need of greater specification. Several potential explicative variables are added to improve the understanding of the changes in environmental degradation. We add three variables in each regression: urbanization (Torras and Boyce, 1998; Erhrhardt-Martinez, 1998; Erhrhardt-Martinez et al., 2002, Shahbaz et al., 2010), petrol price (He and Richard, 2009), and industrialization (Panayotou, 1997; Egli, 2002) in the production-based approach, and energy use (Shahbaz et al., 2010), biocapacity (Bagliani et al., 2008), and life expectancy in the consumption-based approach.

In this paper, we analyze the EKC hypothesis in a time-series dimension for five Latin American countries, Argentina, Brazil, Chile, Colombia and Paraguay, over the period 1971-2007. Latin America is greatly concerned by environmental issues: significant quantities of environmental resources (renewable or not) are used in the economical production structure of these countries. Moreover, they are developing countries becoming increasingly important in the international area. In addition, they have experienced early deindustrialization which may have an impact on their environment.

A large part of the literature focus on the methods (including econometrics) used in the EKC field (see Arrow et al., 1995; List and Gallet, 1999; Aldy, 2005; Galeotti, Manera and Lanza, 2009; Kaika and Zervas, 2013). Indeed, many different methods have been used: (i) traditional parametric model (Grossman and Krueger, 1991; Torras and Boyce, 1998; Stern and Common, 2001; *inter alia*), (ii) vector error correction model (VECM) in order to study cointegration relationship (Perman and Stern, 2003; Dinda and Coondoo, 2006; *inter alia*), and (iii) semi-parametric regressions (Millimet et al., 2003; Bertinelli and Strobl, 2004; *inter alia*). In this paper, we study both short and long run analysis from an Autoregressive Distributed Lagged (ARDL) model developed by Pesaran and Pesaran (1997), Pesaran and Smith (1998), Pesaran and Shin (1999), and Pesaran et al. (2001). There are several advantages to using this model.[1] There is no need to check for the existence of unit roots, and no risk of spurious regressions. The method is completely amenable to a small sample, far more than other cointegration techniques

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[1] Shahbaz et al. (2010), Jalil and Mahmud (2009), Iwata et al. (2010) and Saboori et al. (2012) also use the ARDL approach with CO_2 environmental indicator.

such as the Johansen and Juseliu cointegration model. There is no endogeneity issue because the ARDL model controls for residual correlation. Finally, it also avoids serial correlations.

The article is organized as follows: Section 2 describes the theoretical framework. Section 3 details the variables added to our model. Section 4 presents the econometrical framework and Section 5 the results. Finally, Section 6 gives conclusions.

2 Theoretical Framework

The main explanation of EKC would be the result of three different effects: the scale effect, the technological effect, and the composition effect (Grossman and Krueger, 1991; Panayotou, 1997; De Bruyn et al., 1998; Begun and Eicher, 2007; Meunié and Pouyanne, 2007). The more income increases, the more demand increases, and the more pollution increases with a constant level of pollution per unit of production. This is the scale effect which correlates with environmental degradation. However, with increasing income, surplus wealth can be used to improve production technology and make it less pollution intensive per unit of production. This is called the technological effect and it has an inverse relation with environmental degradation. Lastly, the composition effect reflects changes in economic structure: at first, production is mainly agricultural (very low pollution intensive) and then with economic development, industry (much more polluting) increases. But in the final development phase, the share of the service sector in the economy increases to supplant the industrial sector and the former much less polluting. The composition effect thus first negatively correlates with environmental damage, then positively and finally negatively again as a society develops.

There is a further significant explanation for the EKC corresponding to a demand for environmental quality (Barrett and Graddy, 2000). Once basic needs are satisfied (access to water, food, education, healthcare, etc.), there is a surplus of available income which can be attributed to the environment. Environmental quality being a luxury good[2] could explaining descending curve. However, consumer preferences have an impact on production methods only if they are supported by the public authority. Thus, some authors argue that higher levels of democracy generate lower pollution levels (Barret and Graddy, 2000). Moreover, growth can also increase development, particularly in terms of education and access to information. Consumer awareness

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[2] income elasticity of demand is greater than one

of environmental issues increases, which is the first step towards the expression of preferences for the protection of our ecosystem.

The present study addresses the above theoretical hypotheses by adding a number of variables in order to explain the EKC.

3 Variables

EKC can be considered a black box representing the relationship between an environmental index and economic development. In our case, we study the relationship between Ecological Footprint (EF) and Gross Domestic Product (GDP). Ecological Footprint (EF), introduced by Rees (1992) and developed in Wackernagel and Rees (1996), relates the environmental damage associated with human consumption to the biosphere's regenerative capacity. 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 a predetermined yield (biological productivity) for each 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 factors (such as management decisions and technological inputs). This indicator had been standardized 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 average world yield.

The orientation of study is, of course, very important and the relationship can be approached from the consumption side or supply side. There is no consensus in the field. Choosing the consumption side would avoid a pollution haven bias. However, environmental degradation is mainly caused by industrialization and productions issues. We therefore choose to study from both sides (production and consumption). The difference between the production-side and the consumption-side EF is trade.

$$EF_c = EF_p + EF\ of\ Imports - EF\ of\ Exports \tag{1}$$

where EF_c and EF_p denote the Ecological Footprint of consumption and Ecological Footprint of production, respectively.

The basic equation of the model is the traditional quadratic form of EKC and is defined as:

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

where EF_t stands for the per capita Ecological Footprint (g ha) from supply or consumption-side, during period t, and GDP_t for the per capita GDP per period. b_0 denotes a constant term and ϵ_t is the normally distributed error term.

We add some additional variables in order to improve the accuracy of the EKC.

3.1 Supply side

For the supply side, we add 3 variables: Urbanization, Petrol Price[3] and Industrialization.

First, we include the proportion of urban residents (percentage of the country's population living in urban areas) following Torras and Boyce (1998), Erhrhardt-Martinez (1998), Erhrhardt-Martinez et al. (2002), and Shahbaz, Jalil, and Dube (2010). This is a way to include the demographic changes from rural to large conurbations, as a proxy for structural development. This change is often related to an industrialization phase: farmers leave the country to get a job in industry, in towns. Urbanization is often associated with greater levels of pollution (the Composition Effect). However, it can also facilitate some environmental improvement through economies of scale in the provision of sanitation facilities or a reduction in commuting.

Torras and Boyce (1998) study 42 countries covering the 1977-1991 period and highlight the importance of an equitable distribution of power in the pollution-income relationship. Indeed, they regress seven indicators of air and water quality as a function of GDP plus Gini coefficient, literacy rates and political rights and civil liberties indicators. They also include urbanization in their regression. They use OLS with a cubic function form. They conclude that the EKC relationship seems more like a N-shaped curve.

Next, we include petrol prices as in He and Richard (2009). As petrol becomes increasingly expensive, it could encourage firms to invest in new, less energy-intensive and as a result less

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[3] We also added main commodity production for each country, but results were not significant.

pollution-intensive technologies. This intuition is confirmed by He and Richard's results. They study time series data from Canada from 1948 to 2004 using a semi parametric model and they find an increasing relationship between CO_2 and GDP.

Finally, we add a proxy of industrialization: the share of industry as a percentage of GDP, as in, for example, Panayotou (1997), or Egli (2002), in order to represent the composition effect. Egli (2002) studies time series data concerning Germany from 1966 to 1998. He chooses 8 indicators of air quality (e.g. SO_2, CO_2 and NO_2) as dependant variables and adds to his regression the industrial component of GDP and the imports and exports of goods from pollution-intensive production relative to GDP. The results vary depending on the pollutant.
Panayotou (1997) carries out a cross-sectional analysis for 30 countries from 1982 to 1994. He compares the traditional EKC relationship to a "black box" and, in fact it is in need of greater specification. Therefore he adds rate of income growth, GDP per square kilometre (scale of economic activity) and the weight of industry in GDP (composition of economic activity). The results confirm that the income-pollution relationship is more complex than we could think with the traditional reduced functional form.
To summarize, the basic equation of our model for production-side is now defined as:

$$EF_{c,t} = b_0 + b_1\, GDP_t + b_2\, GDP_t^2 + b_3\, EU_t + b_4\, BC_t + b_5\, LE_t + \epsilon_t \tag{3}$$

where $EF_{c,t}$ stands for per capita Ecological Footprint defined for the consumption-side, GDP_t is per capita Global Domestic Product, EU_t, BC_t, and LE_t denote energy use, biocapacity, and life expectancy, respectively.

3.2 Consumption side

For the EKC from the consumption-side we add 3 explanatory variables: Biocapacity, Life Expectancy and Energy Use.[4]

We can not talk about an ecological footprint without mentioning biocapacity (BC). Biocapacity is the amount of resources nature can supply: it defines how much biologically productive

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[4] We tried to remove the share of low carbon energy of our energy use data but results were not significant

area is available for the provision of particular services. According to the Global Footprint Network (GFN), biological capacity or biocapacity is "The capacity of ecosystems to produce useful biological materials and to absorb waste materials generated by humans, using current management schemes and extraction technologies. "Useful biological materials" are defined as those demanded by human economy. What is considered "useful" can, naturally, change from year to year (e.g. the use of corn (maize) stover for cellulosic ethanol production would result in corn stover becoming a useful material, and thus increase the biocapacity of maize cropland). The biocapacity of an area is calculated by multiplying the actual physical area by the yield factor and the appropriate equivalence factor." Biocapacity, like EF, is expressed in global hectares. Biocapacity is useful for comparison: 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 (see Table 1 and Figure 1).

According to Bagliani, Bravo and Dalmazzone (2008), BC could impact on the EKC. Indeed, the main theoretical argument explaining the decreasing phase of the curve is the consumer behaviour. With income increasing, there tends to be a greater relative demand for services compared to industrial goods (the composition effect) and for more environmental quality, there being a proportion of income available for this (previously, income would be used only for necessary goods).

With a given level of income, in areas where pollution and resource scarcity are important, people would care more about the environment degradation than people who live in areas with an abundance of resources. BC should have a positive correlation with the ecological footprint: the greater the biocapacity is, less the sensitive towards environmental issues people will be, so the greater the ecological footprint will be.

In their study, Bagliani, Bravo and Dalmazzone (2008) analyze the EKC hypothesis from the viewpoint of consumption based measures, using 2001 EF data for 141 countries. They study linear, quadratic and cubic functional forms in standard and logarithmic specifications with both ordinary and weighted least squares methods. They also add a non-parametric analysis. Even where BC is significant, their results do not support the assumptions of the EKC.

As the weakness of GDP as an index of development is now well-documented, we factor in life expectancy at birth another indicator used in HDI. Indeed, GDP is not a perfect indicator of well-being because it takes into account only the increase in value added. The HDI, however, is a qualitative indicator that attempts to account for both economic wealth per person but also the level of health or educational attainment. We try to enhance the information given by per capita GDP by adding indicators linked with quality of life, such as life expectancy at birth.[5]

Finally, we choose to add energy use, expressed in kiloton per capita as in Shahbaz, Jalil, and Dube (2010). Indeed, for the majority of the world, main component of the ecological footprint is energy component (i.e. carbon dioxide emissions). For Latin America it is slightly different, but EF is still correlated to CO_2 (see table2).
Shahbaz, Jalil and Dube (2010) study time series data for Portugal from 1971 to 2008. They use a quadratic functional form with data in logarithmic form and perform an ARDL model. They use CO_2 emissions as environmental indicator and add GDP, trade openness, urbanization rate, and energy use.[6] They find some support for an EKC relationship for Portugal.
To summarize, the basic equation of our model for consumption-side is now defined as:

$$EF_{p,t} = b_0 + b_1\, GDP_t + b_2\, GDP_t^2 + b_3\, URB_t + b_4\, PP_t + b_5\, INDU_t + \epsilon_t \tag{4}$$

where $EF_{p,t}$ stands for per capita Ecological Footprint defined for the supply-side, GDP_t is per capita Global Domestic Product, URB_t, PP_t, and $INDU_t$ denote urbanization ratio, petrol price, and industrialization ratio, respectively. b_0 denotes a constant, and ϵ_t is the normally distributed error term.

4 Econometrical Framework

We perform an ARDL estimation (autoregressive distributed lagged model) introduced by Pesaran and Pesaran (1997) and developed by Pesaran and Smith (1998), Pesaran and Shin (1999) and Pesaran et al. (2001). There are several advantages to use this model: It does not matter if the variables are I(1) or I(0) (no need to control for existence of unit roots). The model is completely amenable to a small sample, far more than other cointegration techniques such as

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[5] Unfortunately, data on educational attainment are not available for our sample.

[6] We already work on consumption side in order to avoid heaven pollution bias thus we choose to not add trade openness. We add urbanization rate in our supply side study.

the Johansen and Juseliu cointegration model. There is no more endogeneity issue because the ARDL model control for residual correlation. It also avoids serial correlations.

The ARDL framework for equations 4 and 3 is as follows:

$$\begin{aligned}\Delta EFp_t = b_0 + \beta_1\, lnEFp_{t-1} + \beta_2\, lnGDP_{t-1} + \beta_3\, lnGDP^2_{t-1} + \beta_4\, lnURB_{t-1} + \beta_5\, lnPP_{t-1} \\ +\beta_6\, lnINDU_{t-1} + \sum_{k=1}^{1} b_1\, \Delta lnEFp_{t-k} + \sum_{k=0}^{1} b_2\, \Delta lnGDP_{t-k} + \sum_{k=0}^{1} b_3\, \Delta lnGDP^2_{t-k} \\ + \sum_{k=0}^{1} b_4\, \Delta lnURB_{t-k} + \sum_{k=0}^{1} b_5\, \Delta lnPP_{t-k} + \sum_{k=0}^{1} b_6\, \Delta lnINDU_{t-k} + \epsilon_t\end{aligned} \tag{5}$$

$$\begin{aligned}\Delta EFc_t = b_0 + \beta_1\, lnEFc_{t-1} + \beta_2\, lnGDP_{t-1} + \beta_3\, lnGDP^2_{t-1} + \beta_4\, lnEU_{t-1} + \beta_5\, lnBC_{t-1} \\ +\beta_6\, lnLE_{t-1} + \sum_{k=1}^{1} b_1\, \Delta lnEFc_{t-k} + \sum_{k=0}^{1} b_2\, \Delta lnGDP_{t-k} + \sum_{k=0}^{1} b_3\, \Delta lnGDP^2_{t-k} \\ + \sum_{k=0}^{1} b_4\, \Delta lnEU_{t-k} + \sum_{k=0}^{1} b_5\, \Delta lnBC_{t-k} + \sum_{k=0}^{1} b_6\, \Delta lnLE_{t-k} + \epsilon_t\end{aligned} \tag{6}$$

where b_1, b_2, b_3, b_4, b_5, b_6 represent the error correction dynamics, and β_1, β_2, β_3, β_4, β_5, β_6 correspond to the long-run relationship.

First, we estimate ARDL regression (Equations 5 and 6) by ordinary least square (OLS) in order to perform a Wald Test on estimated coefficients. (H0: Coefficients β_i are equals to zero. H1: coefficients β_i are significantly different from zero.) Calculated F value is compared to critical values (upper and lower boundaries) provided by Pesaran and Pesaran (1997).

If the calculated F value is less than the lower critical value, the null hypothesis of no cointegration can not be rejected. If F value is between the two critical values, the test is inconclusive. If calculated F value is greater than the highest critical value, the null hypothesis of no cointegration is rejected. In this case, we would explore the cointegration relationship between our variables. Results are provided in Table 3 and Table 9.

Next, we proceed to the long run estimation (Table 4 and Table 10) keeping only significant variables. (Tables 5 and 11). From these coefficients, we build an error correction term (ECT_{t-1})

when a cointegration relationship has been detected during the first step. We can estimate the short run relationship using first differences (Tables 6 and 12):

$$\Delta EFp_t = b_0 + b_1\,\Delta lnEFp_{t-1} + b_2\,\Delta lnGDP_{t-1} + b_3\,\Delta lnGDP^2_{t-1} \qquad (7)$$
$$+b_4\,\Delta lnURB_{t-1} + b_5\,\Delta lnPP_{t-1} + b_6\,\Delta lnINDU_{t-1} + \theta\,ECT_{t-1} + \epsilon_t$$

$$\Delta EFc_t = b_0 + b_1\,\Delta lnEFc_{t-1} + b_2\,\Delta lnGDP_{t-1} + b_3\,\Delta lnGDP^2_{t-1} \qquad (8)$$
$$+b_4\,\Delta lnEU_{t-1} + b_5\,\Delta lnBC_{t-1} + b_6\,\Delta lnLE_{t-1} + \theta\,ECT_{t-1} + \epsilon_t$$

Finally, we keep only the significant variables (Tables 7 and 13).

5 Empirical Results

5.1 Data

For the purpose of our analysis, we consider annual time series data for five Latin American countries covering the period 1971-2007. Our analysis focuses on Argentina, Brazil, Chile, Colombia, and Paraguay.[7]

Per capita Ecological Footprint (consumption and supply sides) (EF) and per capita Biocapacity (BC) data come from the Global Footprint Network (GFN).[8] Per capita GDP, expressed in US$ (2000 prices), life expectancy, energy use, urbanization, industrialization are obtained from the World Bank. Finally, petrol prices come from Dow Jones & Company.

5.2 Results

5.2.1 Production-side approach

All countries show a long run cointegration relationship, except for Argentina. However, each all error correction terms are significant but positive, meaning there seems to be a separation in the

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[7] We had to remove Peru because there is missing data from 1979 to 1986 and Uruguay because of a short sample beginning in 1983, for some variables such as industrialization rate

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

long-run. In consequence, we chose to remove error correction terms and focus to the short-run analysis (Table 8).

Considering the short-run analysis, our study does not support EKC assumptions: We find an increasing linear relationship for four countries (Brazil, Chile, Colombia and Paraguay) suggesting EF worsen as per capita income increases, and no significant relationship for Argentina. We note that for Chile, the ratio of industrialization is significant and positive. We might think that Chile is still in the second phase (the service sector is not yet well-developed) so the composition effect is positive for the ecological footprint. To check this assumption, we compare the ratio for services (as a percentage of GDP): in 2009, it was 58.84% for Chile, while it was around 79% for North America and France. Note that none of other explicative variables seem to be significant.

5.2.2 Consumption-side approach

Results for the consumption-side approach are mixed: There seems to be a long run cointegration relationship between GDP and Ecological Footprint in Brazil and Colombia but the error correction terms are significant and positive suggesting a separation in the long-run. There is no cointegration relationship for Chile and no conclusion can be drawn for Argentina and Paraguay. As previously, we removed positive error correction terms and we focus on short-term analysis (Table 14).

For the short-run analysis, there is no significant relationship for Argentina and Paraguay between EF and GDP. Brazil, Chile and Colombia exhibit a linear increasing relationship, suggesting as from the production-side approach that an increase in per capita income results in an increase of the ecological footprint. We note that energy use is positive and significant for Argentina and Colombia. This result is coherent with the significant place of carbon use in EF components for these two countries (See Figures 3(a) and 3(g) and Table 15). Indeed, carbon components represents in mean almost 16% of total EF for Argentina and Colombia. For Paraguay, biocapacity is significantly positive while life expectancy is significant and negative, as expected. It could be supposed that when BC is high enough, it has a significant impact on environmental behaviour. Paraguay has an high BC level (19.65 gah on average during the period, while the biocapacity of the other countries in our sample average 7.72 gah) and the higher ecological reserve (15.8 gah on average during the period, see Table 1). It seems that Paraguay is a such productive place that its inhabitants do not care a great deal about the environment. Life expectancy significantly impacts negatively on EF, we could think that as development improves, awareness of environmental issues also increases, so EF decreases.

6 Conclusion

In this paper we examined the Environmental Kuznets Curve (EKC) hypothesis using Ecological Footprint (EF), a more comprehensive indicator of environmental degradation, in a time series dimension for 5 Latin American countries covering the 1971-2007 period. We added several explicative variables and studied both consumption and production in order to detail the relationship between environment and growth. We performed an ARDL model in order to study both the short and long run period. However, it appears there is no long run equilibrium for these countries. The short run analysis highlights the fact that the EKC hypothesis is supported for none of the countries. We find an increasing relationship for Brazil, Chile and Colombia for both production and consumption, and Paraguay for production. In addition, the results for the additional variables are mixed but coherent with what we expected: For production-side approach, industrialization appears to have a positive impact on EF for Chile. For consumption-side approach, we find that energy use seems to have a positive impact on EF for Argentina and Colombia whereas biocapacity and life expectancy have a positive and negative impact, respectively, on EF for Paraguay.

To conclude, environmental policies are central: growth alone would appear to be not enough to improve environmental conditions. Latin America has to deal with a real challenge: Development must be sustainable considering the increasing number of international agreements on the environment, even if growth seems to lead to an increasing ecological footprint. Arbitration is difficult as the priority for the authorities is to ensure a rise in welfare for the population. However, it could say that environmental issues can not be deferred, as it was in the developed countries. The earlier development is sustainable, the better it is for the state of the environment.

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Table 1: Comparison between EF_c and BC (in mean).

Country	EE_c	BC	Comparison	Δ
Argentina	3.31	8.22	Ecological Reserve	$+$ 4.91
Brazil	2.89	12.11	Ecological Reserve	$+$ 9.22
Chile	2.41	4.78	Ecological Reserve	$+$ 2.37
Colombia	2.12	5.74	Ecological Reserve	$+$ 3.62
Paraguay	3.85	19.65	Ecological Reserve	$+$ 15.8

Table 2: Correlation between EF (consumption side) and CO_2.

Country	R	T-stat	P-value
Argentina	-0.0602	-0.36	0.72
Brazil	0.3644	2.31^{**}	0.03
Chile	0.8681	10.35^{***}	0.00
Colombia	0.2873	1.77^{*}	0.08
Paraguay	0.1277	0.76	0.45

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

Table 3: Existence of cointegration relationship (ARDL-Supply.)

Country	Wald Test	Conclusion
Argentina	2.11	No cointegration
Brazil	10.26	Cointegration
Chile	3.71	Cointegration
Colombia	4.44	Cointegration
Paraguay	3.66	Cointegration

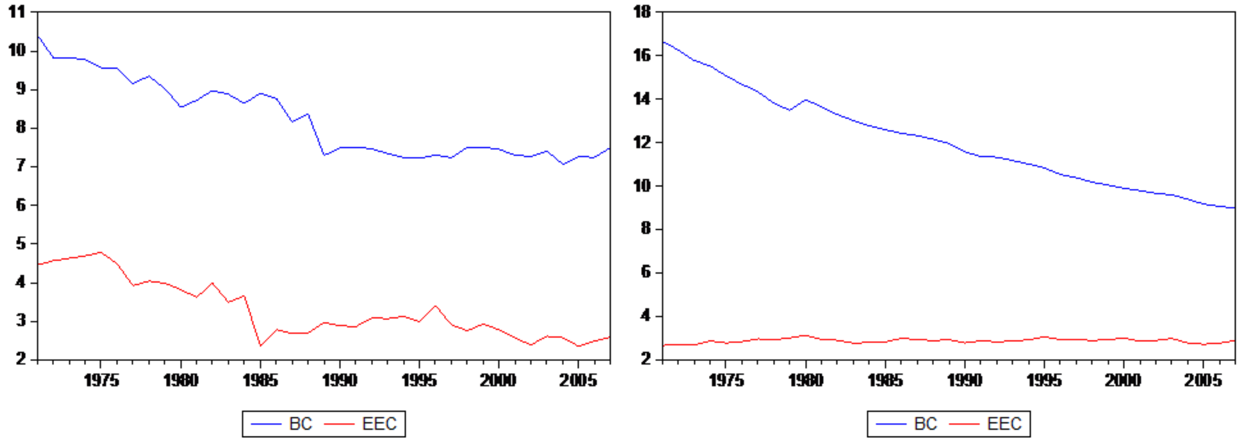
Notes: $d(ln(eep)) = b_0 + b_1 ln(pib_{-1}) + b_2 ln(pib2_{-1}) + b_3 ln(indu_{-1}) + b_4 ln(pp_{-1}) + b_5 ln(urb_{-1}) + b_6 ln(eep_{-1}) + d(ln(pib)) + d(ln(pib_{-1})) + d(ln(pib2)) + d(ln(pib2_{-1})) + d(ln(indu)) + d(ln(indu_{-1})) + d(ln(pp)) + d(ln(pp_{-1})) + d(ln(urb)) + d(ln(urb_{-1})) + d(ln(eep_{-1})) + \epsilon_t$

Table 4: Results of long run OLS estimations (Supply).

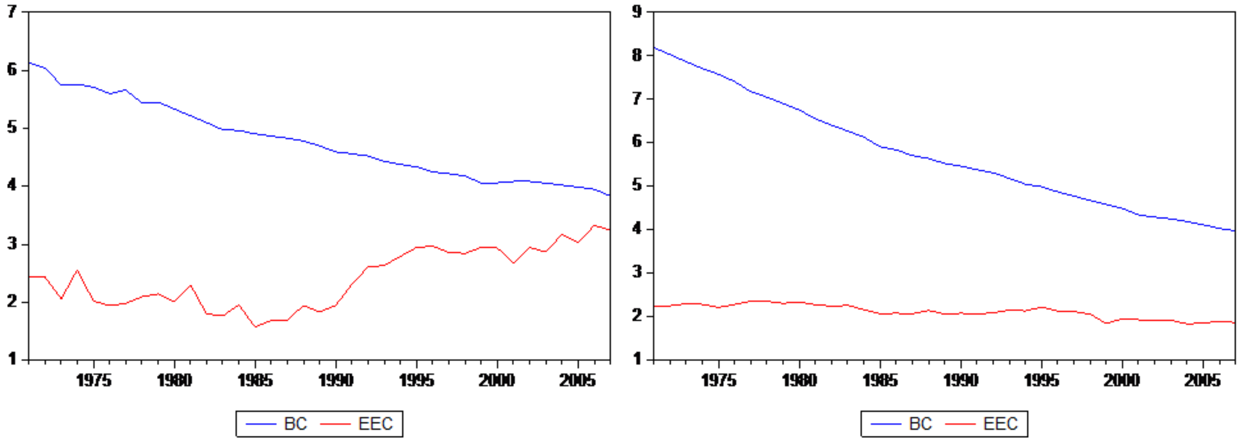
Country	c	GDP	GDP^2	Urbanization	Petrol Price	Industrialization
Argentina	-41.796 (-0.632)	10.281 (0.706)	-0.548^{*} (-0.667)	-1.191 (-1.987)	0.038 (1.159)	0.148 (1.018)
Brazil	20.065^{**} (2.174)	-5.132^{**} (-2.221)	0.330^{**} (2.275)	0.182^{*} (1.795)	0.033^{***} (2.834)	0.027 (0.956)
Chile	-52.676^{***} (-6.097)	10.607^{***} (4.637)	-0.625^{***} (-4.515)	2.044^{**} (2.636)	-0.017 (-0.508)	0.029 (0.169)
Colombia	-86.066^{***} (-10.426)	24.986^{***} (11.133)	-1.567^{***} (-11.064)	-3.076^{***} (-13.078)	-0.028^{***} (-3.452)	0.103^{**} (2.385)
Paraguay	-28.116^{**} (-2.413)	8.293^{**} (2.490)	-0.545^{**} (-2.302)	-0.290^{***} (-3.524)	-0.051^{***} (-3.534)	-0.149 (-1.409)

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

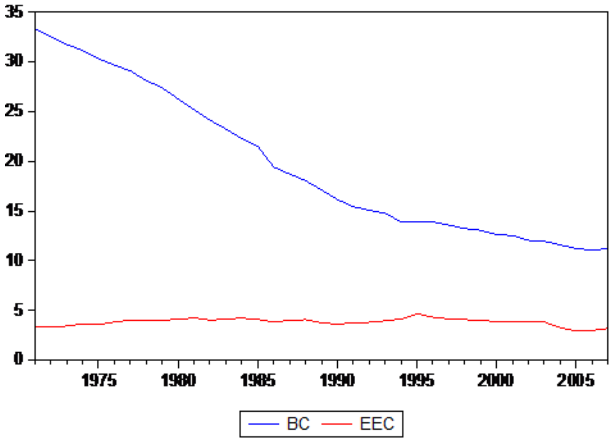
Figure 1: BC and EF_c



(a) Argentina (b) Brazil



(c) Chili (d) Colombia



(e) Paraguay

Table 5: Results of long run OLS estimations (Supply)2.

Country	c	GDP	GDP^2	Urbanization	Petrol Price	Industrialization
Argentina	4.389^{***} (3.318)	0.552^{***} (4.479)		-1.752^{***} (-6.060)	0.054^{**} (2.064)	
Brazil	20.891^{**} (2.525)	-5.238^{**} (-2.542)	0.344^{**} (2.688)		0.023^{***} (2.737)	
Chile	-54.018^{***} (-7.305)	11.203^{***} (6.184)	-0.660^{***} (-5.945)	1.784^{***} (3.053)		
Colombia	-86.066^{***} (-10.426)	24.986^{***} (11.133)	-1.567^{***} (-11.064)	-3.076^{***} (-13.078)	-0.028^{***} (-3.452)	0.103^{**} (2.385)
Paraguay	-28.195^{**} (-2.383)	8.177^{**} (2.419)	-0.542^{**} (-2.257)	-0.210^{***} (-3.466)	-0.050^{***} (-3.373)	

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

Table 6: Results of short run OLS estimations (Supply).

Country	c	dGDP	dGDP^2	dUrbanization	dPetrol Price	dIndustrialization	ECT_{t-1}
Argentina	0.047 (0.905)	2.773 (0.179)	-0.155 (-0.177)	-11.934 (-0.976)	-0.007 (-0.163)	-0.042 (-0.225)	
Brazil	-0.000 (-0.102)	-4.352 (-1.153)	0.289 (1.227)		0.015 (1.009)		0.655^{***} (3.912)
Chile	0.018 (1.673)	10.145^{**} (2.330)	-0.616^{**} (-2.218)				0.441^{***} (3.123)
Colombia	-0.015^{*} (-1.721)	9.301^{*} (1.902)	-0.561^{*} (-1.781)	-0.823 (-0.746)	-0.010 (-0.928)	0.138^{**} (2.109)	0.425^{**} (2.634)
Paraguay	0.022 (0.538)	2.085 (0.358)	-0.116 (-0.284)	-1.660 (-0.549)	-0.029 (-1.147)		0.804^{***} (4.623)

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

Table 7: Results of short run OLS estimations (Supply) 2.

Country	c	dGDP	dGDP^2	dUrbanization	dPetrol Price	dIndustrialization	ECT_{t-1}
Argentina							
Brazil	-0.000 (-0.052)	0.304^{***} (3.240)					0.672^{***} (4.034)
Chile	0.004 (0.482)	0.494^{***} (3.044)				0.319^{**} (2.322)	
Colombia	-0.021^{***} (-6.227)	6.865^{*} (2.005)	-0.405^{*} (-1.834)			0.130^{*} (2.014)	0.429^{***} (2.894)
Paraguay	0.000 (0.078)	0.396^{***} (3.036)					0.756^{***} (4.643)

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

Table 8: Results of short run OLS estimations (Supply)3.

Country	c	dGDP	dGDP^2	dUrbanization	dPetrol Price	dIndustrialization
Argentina						
Brazil	0.001 (0.129)	0.256^{**} (2.282)				
Chile	0.004 (0.482)	0.494^{***} (3.044)				0.319^{**} (2.322)
Colombia	-0.019^{***} (-5.137)	0.563^{***} (4.451)				
Paraguay	-0.001 (-0.123)	0.461^{***} (2.810)				

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

Table 9: Existence of cointegration relationship (ARDL-Demand.)

Country	Wald Test	Conclusion
Argentina	3.31	Inconclusive
Brazil	4.88	Cointegration
Chile	2.05	No cointegration
Colombia	4.39	Cointegration
Paraguay	2.52	Inconclusive

Notes: .

Table 10: Results of long run OLS estimations (Demand).

Country	c	GDP	GDP^2	Energy Use	Biocapacity	Life Expectancy
Argentina	-39.392 (-0.495)	17.139 (0.971)	-0.924 (-0.922)	-0.049 (-0.077)	-0.713^{*} (-1.995)	-8.641^{***} (-5.554)
Brazil	-26.611 (-1.667)	3.892 (1.181)	-0.222 (-1.048)	0.040 (0.164)	0.881^{**} (2.093)	1.966^{*} (1.831)
Chile	15.811 (1.197)	-0.318 (-0.130)	0.085 (0.546)	-0.168 (-0.492)	-0.413 (-0.407)	-3.764^{**} (-2.162)
Colombia	-17.507 (-1.617)	3.885 (1.139)	-0.221 (-1.010)	0.127 (1.402)	0.665^{***} (3.160)	-0.118 (-0.139)
Paraguay	-37.075 (-1.424)	12.388^{*} (1.819)	-0.866^{*} (-1.775)	0.638^{***} (2.784)	0.127 (0.723)	-2.457 (-1.276)

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

Table 11: Results of long run OLS estimations (Demand)2.

Country	c	GDP	GDP^2	Energy Use	Biocapacity	Life Expectancy
Argentina	34.626^{***} (6.090)	0.733^{***} (4.605)			-0.740^{**} (-2.102)	-9.002^{***} (-6.958)
Brazil	-12.488^{**} (-2.403)	0.394^{***} (5.624)			0.899^{**} (2.517)	1.940^{*} (1.978)
Chile	9.836^{***} (6.706)		0.058^{***} (13.472)			-2.987^{***} (-7.473)
Colombia	-4.930^{***} (-5.036)	0.430^{***} (3.350)		0.188^{**} (2.517)	0.659^{***} (6.745)	
Paraguay	-29.639 (-1.248)	12.169^{*} (1.802)	-0.851^{*} (-1.759)	0.533^{**} (3.028)		-3.781^{**} (-6.380)

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

Table 12: Results of short run OLS estimations (Demand).

Country	c	dGDP	dGDP^2	dEnergy Use	dBiocapacity	dLife expectancy	ECT_{t-1}
Argentina	-0.026 (-0.300)	15.859 (0.645)	-0.897 (-0.646)	0.936 (1.447)	-0.331 (-0.661)	0.817 (0.031)	
Brazil	-0.005 (-0.198)	0.468^{***} (4.417)			0.591 (1.653)	1.513 (0.337)	0.583^{***} (3.584)
Chile	0.028 (0.443)	9.110 (0.872)	-0.549 (-0.820)	0.687 (1.380)	1.305 (0.981)	-2.836 (-0.396)	
Colombia	-0.001 (-0.058)	0.553^{***} (2.910)		0.284^{**} (2.190)	0.779 (1.237)		0.567^{***} (3.584)
Paraguay	0.099^{**} (1.936)	-2.522 (-0.270)	0.181 (0.276)	0.159 (0.711)	1.190^{**} (2.369)	-27.086^{*} (-1.758)	

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

Table 13: Results of short run OLS estimations (Demand)2.

Country	c	dGDP	dGDP^2	dEnergy Use	dBiocapacity	dLife expectancy	ECT_{t-1}
Argentina	-0.023 (-1.387)			0.950^{**} (2.196)			
Brazil	-0.007 (-1.594)	0.499^{***} (4.769)					0.639^{***} (4.019)
Chile	-0.022 (-1.266)	1.121^{***} (3.803)					
Colombia	-0.018^{***} (-3.491)	0.626^{***} (3.438)		0.269^{**} (2.067)			0.529^{***} (3.380)
Paraguay	0.114 (2.952)				1.258^{***} (2.851)	-31.628^{**} (-2.545)	

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

Table 14: Results of short run OLS estimations (Demand)3.

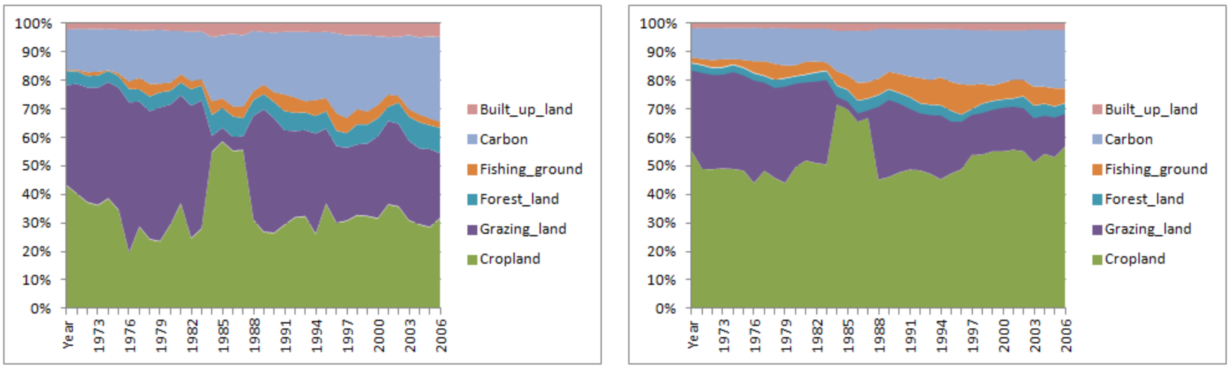
Country	c	dGDP	dGDP^2	dEnergy Use	dBiocapacity	dLife expectancy
Argentina	-0.023 (-1.387)			0.950^{**} (2.196)		
Brazil	-0.007 (-1.271)	0.473^{***} (3.768)				
Chile	-0.022 (-1.266)	1.121^{***} (3.803)				
Colombia	-0.017^{***} (-2.871)	0.577^{***} (2.769)		0.330^{**} (2.229)		
Paraguay	0.114 (2.952)				1.258^{***} (2.851)	-31.628^{**} (-2.545)

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

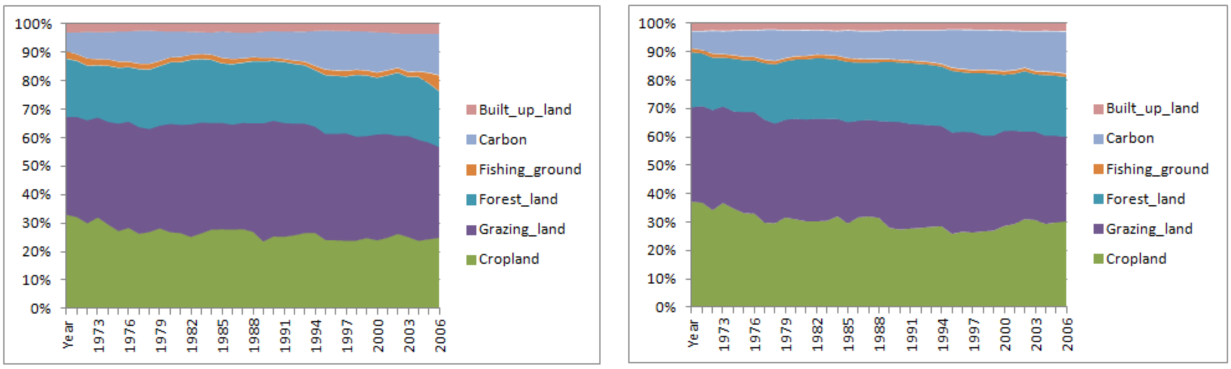
Table 15: Shares in % of EF components (means)

Country	Side	Total	Cropland	Grazing land	Forest land	Fishing ground	Carbon	Built up land
Argentina	EF_c	3.31	34.06%	32.11%	5.91%	3.36%	21.22%	3.34%
	EF_p	5.28	51.89%	21.70%	3.26%	5.47%	15.68%	1.99%
Brazil	EF_c	2.89	26.62%	37.10%	20.74%	1.84%	10.94%	2.76%
	EF_p	3.17	30.29%	34.69%	20.42%	1.10%	10.98%	2.51%
Chile	EF_c	2.41	27.84%	16.22%	25.51%	8.74%	18.95%	2.73%
	EF_p	3.40	15.59%	11.23%	28.54%	24.63%	18.09%	1.92%
Colombia	EF_c	2.12	21.66%	46.25%	7.97%	1.85%	17.71%	4.55%
	EF_p	2.08	23.37%	48.13%	7.09%	0.87%	15.86%	4.68%
Paraguay	EF_c	3.85	19.37%	49.42%	22.75%	0.19%	5.62%	2.65%
	EF_p	4.68	31.07%	44.74%	19.26%	0.11%	2.65%	2.16%

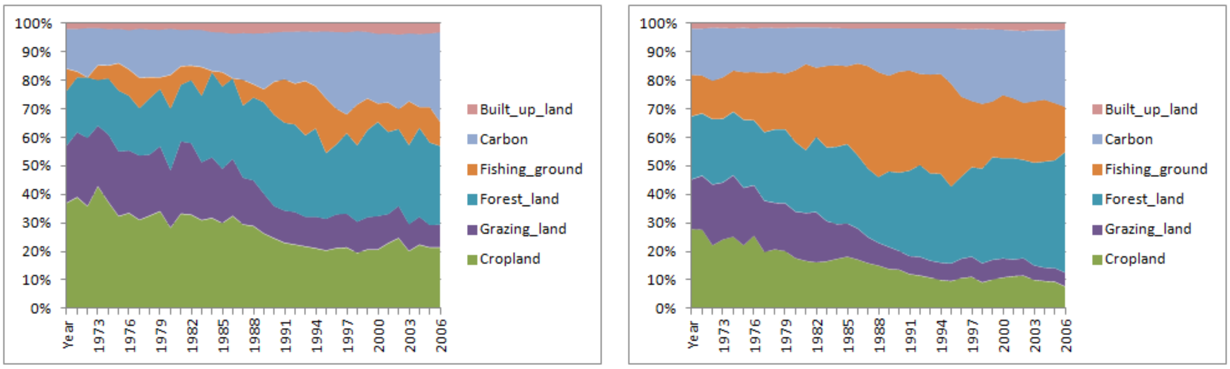
Figure 2: Shares of EF components



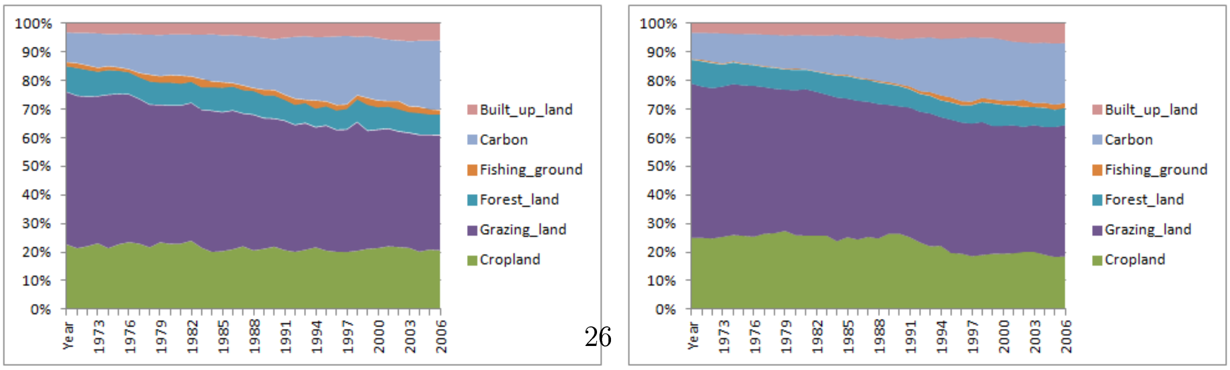
(a) Argentina EF_c (b) Argentina EF_p



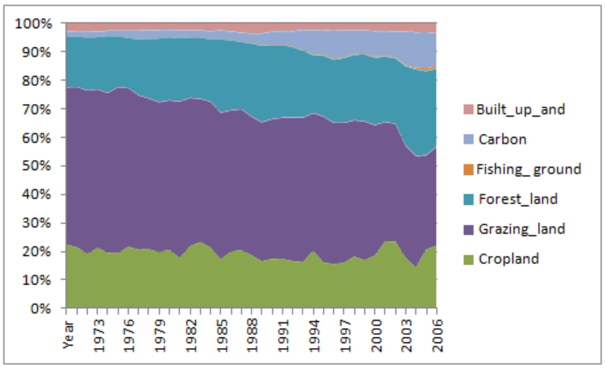
(c) Brazil EF_c (d) Brazil EF_p



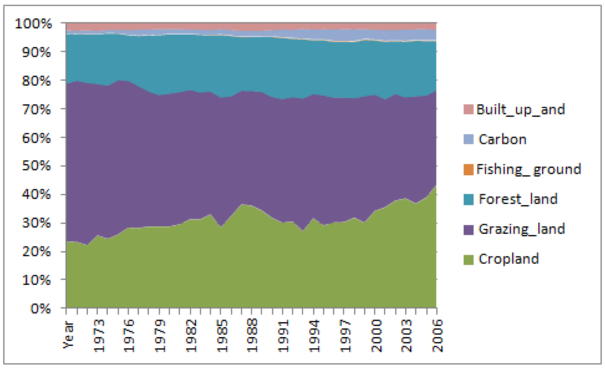
(e) Chili EF_c (f) Chili EF_p



(g) Colombia EF_c (h) Colombia EF_p



(i) Paraguay EF_c



(j) Paraguay EF_p