Energy consumption, income, and CO_2 emissions in Latin America

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Resumen

I describe and compare the environment policies of European Union and of 12 Latin Americans economies. For this, I use common statistical methods, such as non-parametric tests, convergence analysis (β y σ) and panel data, in order to verify the hypothesis that emissions and energy use in Latin America has been increasing since the mid-20th century. The statistical tests used confirm the proposed hypothesis. I also rely upon the *Environmental Kuznets Curve*- whereby economies that are at the growth stage are more focused on achieving the latter than they are on environmental concerns and those which have already achieved growth focus more on environmental concerns-to take an alternative approach by introducing the role of economic growth in the evolution of energy consumption and emissions. This chapter reaches the conclusion that energy consumption and pollutant emissions in LA, in per capita terms, are converging. This suggests that the initial levels of the variables help to explain why some countries have increased emissions (in this case, energy consumption) to a greater extent than other economies in the region. Evidence of convergence is also found, as well as a monotonic relationship between the level of pollution and the level of development (consistent with the Environmental Kuznets Curve).

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1. The air pollution issue

Interest in the protection of the environment has grown during the past decades thanks to new and alarming scientific discoveries. Pollution has damaged the environment through time by different vehicles: air, water and soil pollution have all been increasing at expenses of a safe and clean environment, human health and life in general.

The most "Trans-National" way by which pollution affects the environment is represented by emissions through the "air". As a matter of fact, scientists during the 1960s demonstrated the existence of a connection between sulphur emissions in continental Europe and the acidification[1] of Scandinavian lakes. This means that atmospheric pollutants can travel, thanks to the wind, several thousands kilometers before deposition and damage occur. Therefore, *Transboundary Pollution*, as it is defined, is directly related to phenomena such as acidification and eutrophication[2] mainly provoked by anthropogenic emissions of Nitrogen Oxides (NO_x), especially Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2) and Ammonia (NH_3). Anthropogenic NO_x are mainly contained in the exhaust emissions of diesel and petrol powered "on" and "off-road" engines; exhaust emissions come from the incomplete fuel combustion during engine operation. Such incomplete combustion occurs mainly in the operation of "on-road" engines (motor vehicles), even if a consistent proportion comes from "off-road" engines, as it is the case of combustion for energy production. SO_2 emissions come mainly from the combustion of poor-quality coal and petroleum in energy production activities and partly from that of sulphur-containing fuels (diesel) in motor vehicles. NH_3 emissions are directly related to the use of fertilizers in agriculture. The deposition of these pollutants causes the loss of fisheries in water, the impoverishment of the soil and dangerous effects on vegetation. In particular, the action of nitrogen containing compounds favors both terrestrial and marine eutrophication.

Together with their transboundary effects, some of these pollutants

[1]"Acidification" is the change in the natural chemical balance of an environment, caused by an increased concentration of acid elements.

[2]"Eutrophication" is the excessive enrichment of an ecosystem with nutrients that determines lots of adverse biological effects.

have other dangerous consequences when persisting into the air, no matter if they travel lots of kilometers or not. NO_x, for instance, react in the presence of solar radiation with other chemical compounds to form *Tropospheric (or Ground-Level) Ozone*[3], a highly corrosive and poisonous substance representing the key ingredient of urban smog. As a consequence, NO_x are also defined "Ozone Precursors" a category of pollutants that includes gases like Carbon Monoxide (CO) and Non-Methane Volatile Organic Compounds ($NMVOC$). Anthropogenic CO is chiefly contained in the petrol and diesel powered vehicles exhaust[4] and contribute by the largest part to the formation of the smog. $NMVOC$ emissions come largely from the evaporation that occurs for the use of solvents in certain industrial processes and at a smaller scale from exhaust of motor vehicles.

The international community first legally binding instrument to combat air pollution is represented by the *Convention on Long-Range Transboundary Air Pollution* (CLRTAP), initially signed by 34 governments and the European Union (EU) in 1979 in Geneva. The Convention entered into force in 1983 and has been extended by specific protocols including different pollution aspects. Now it counts 49 parties and it still represents the foundation of cooperation against the air pollution problem, at a world level. Some of its first protocols contain measures to combat both acidification and eutrophication problems; during the 1990s, it began to face the tropospheric ozone issue.

Some decades after the discovery of the "trans-national" aspect of certain emissions, researchers led the scientific debate on air pollution to a new phase where a more worldwide engagement is needed. They discovered the dangerous consequences of another pollution problem, the *Climate Change* one, that by now represents the most global consequence of air pollution. Changes in Earth temperature are demonstrated to be a direct result of rising "greenhouse gases", specific at-

[3]Ozone exists in two layers of the atmosphere, the stratosphere and the troposphere. The last one corresponds to that near Earth surface or, better said, it corresponds to the air we breathe. Here ozone presence is dangerous for both health and environment

[4]CO production is a direct function of the air/fuel ratio in the engine. When air supply is restricted, for instance during vehicle starting or at altitude where "thin" air reduces oxygen available for combustion, the incomplete fuel combustion is higher and so is CO generation.

mospheric components that form a sort of protective blanket around the Earth, slowing down the rate at which heat from planet surface radiates out into the space. The main responsible gases are six, Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFC), Perfluorocarbons (PFC)and Sulphur Hexafluoride (SF_6). Among all these gases, CO_2 shows the largest proportion at a world level; actually it is the most known greenhouse gas. Its emissions are mainly produced by the combustion of substances containing carbon, namely coal, petroleum and its derivatives. For this reason, its presence is directly related to the production of energy and to its use in the form of electricity and carbon containing fuels.

The first global agreement addressing the greenhouse gases problem came in 1992, the *United Nations Framework Convention on Climate Change* (UNFCCC). It aimed principally to stabilize by 2000, in industrialized countries, anthropogenic CO_2 emissions at 1990 levels and set up global monitoring and reporting mechanisms for the control of such emissions. The UNFCCC entered into force in 1994, after being ratified by 50 countries among which the EU Members. It is now approaching universal membership (more than 180 parties). The next important step came in 1997, when the UNFCCC signatories agreed, in Kyoto, on a protocol setting a number of binding quantitative targets for global greenhouse gases cuts. The general target of the *Kyoto Protocol*, as it is known, is represented by the reduction of the six greenhouse gases emissions of 5 % below 1990 levels by 2008, latest 2012. In compliance of the Kyoto target, the EU has established a bigger cut, 8 % below 1990 levels, to be reached over the same period by Member States.

The protocol proposes the possibility of setting up an emissions trading scheme among the parties to reach the target; unfortunately, by now there are no positive insights of any progress in this direction, except for the European Union that has a Directive to be implemented in 2008. The idea of building up an emissions trading scheme inside the EU, has come out in 2000 (to be implemented by 2007) with the proposition of the *Greenhouse Gas Emissions Trading and Climate Change Programme*. It stresses the need of a detailed scheme according to which, each Member State develops a national plan indicating the allowances[5] it intends to allocate for the relevant period and how it is going to decide the allocation. In spite of the intent of creating a binding regulatory framework of the trading scheme[6], its implementation is still at a preliminary phase. The emissions trading programme is part of a general strategy resumed by the *European Climate Change Programme* (ECC), proposed in 2000 with the aim of reducing the greenhouse gases emissions inside the Union through the coordination of all corresponding policies and instruments.

The implementation and integration of these general programmes in many cases has led the EU to issue some legislative texts, namely Directives, establishing national targets for most pollutants, according to their particular nature. Such targets can be resumed as follows:

- the fixing of mandatory “National Emissions Ceilings”[7] with the corresponding time frames[8];
- the definition of “limit values”[9] for the concentration of specific pollutants in “ambient air”[10] and the corresponding time frames.

1.1. The Environmental Kuznets Curve (EKC)

The existing empirical environmental literature does not pay much attention to convergence. Rather, that literature focuses on the estima-

[5].Emissions Allowance”means an allowance to emit one metric tonne of CO_2 or an amount of any other greenhouse gas with an equivalent global warming potential, during a specified period and which is transferable according to the corresponding legal text (Proposal for a Directive, Communication (2001)581 final).

[6]A legal text establishing the details of the trading scheme entered into force only on the past 13th of October 2003 (Directive 2003/87/EC).

[7]“National Emissions Ceiling” means the maximum amount of a substance expressed in kilotonnes, which may be emitted from a Member State in a calendar year (Directive 2001/81/EC).

[8]In the case of the *Kyoto Protocol*, the setting of quantitative reduction targets could be seen as the establishment of emissions ceilings.

[9]“limit value” means a level fixed on the basis of scientific knowledge, with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole, to be attained within a given period and not to be exceeded once attained, where “level” indicates the concentration of a pollutant in ambient air (Directive 96/62/EC) and is usually expressed in volume terms.

[10]“ambient air” means outdoor air in the troposphere, excluding work places (Directive 96/62/EC).

tion of the well-known environmental Kuznets curve [Grossman and Krueger[3], Holtz-Eakin and Selden[4], Panayotou[5] and Selden and Song[8], among many others]. Those papers connect the evolution of per capita pollution levels with the evolution of GDP levels. Without mention to specific functional forms relating both variables, there is a general agreement in an inverted-U shaped curve: as a country gets developed, its pollution level first increases and then decreases over time. There is also a body of theoretical literature that derives such behavior from the fundamental assumption of considering the air quality as a normal good (see Kelly (2003) for a recent discussion). However, whether all countries are bounded to go in the long run along the same Kuznets curve or, contrarily, there are country-specific Kuznets curves remains an open question.

2. European and LA Environmental Efforts

2.1. Europe

EU legislative activity in the field of air pollution, especially when related to the ozone precursors issue, appears to be even more comprehensive regarding Latin American (LA) countries. Once the main sources of emissions of specific pollutants, namely CO, $NMVOC$ and NO_x, have been identified as some relevant economic sectors, the Community began to issue legislative instruments in order to regulate their activity from an environmental point of view.

Before the adoption of the CLRTAP, the EU had already set up its own first environmental programme in 1973, the *Five-Years Environmental Action Programme* (5EAP). However, it is only with the fifth edition of the 5EAP, come into force in 1993, that the European Union (EU) established objectives, targets, actions and time frames to be implemented and reached in the coming decade, according to the “sustainable development” principle. The fifth programme proposes actions on most of the polluting emissions included in the CLRTAP as last updated, mainly NO_x, SO_2, NH_3, CO and $NMVOC$. More recently, the EU has integrated its environmental strategy by stressing the importance of the control and prevention of health effects caused by acidifying and ozone precursors emissions. In this line, in 2001, it has proposed the

Clean Air for Europe Programme (CAFE).

It is clear that the air pollution issue includes very different aspects that have been faced by different kinds of measures. There are the transboundary and the tropospheric ozone issues from one side and the climate change from the other. EU activity covers all these themes at an extra Union level as well as inside its frontiers. The engagement in international programmes has led to the setting of pollutant targets, sometimes by means of legislative instruments, without taking into account pollution sources, that is to say the relevant economic activities involved. The engagement at EU level has led to the creation of a body of measures, mainly legislative, specifically directed to the activities of certain economic sectors, main sources of air pollution. Activity in this direction can be resumed as follows:

- the reduction of polluting emissions from the *Road Transport* sector;
- the control and, when possible, the reduction of polluting emissions from the *Industry* sector.

The aim of this section is to go throughout this specific body of measures adopted at EU level and representing the bulk of EU environmental activity, in order to analyze its economic implication and suggest what has been left and could be desirable to do. Further on, to take EU's experience in LA and begin a similar initiative, given the successful results attained by Europe. Appendix I presents a summary of specific European environmental measures on air pollution.

2.2. Latin America Environmental Efforts

The previous section stressed the importance of combating air pollution. Also the types of international initiatives that to this end the EU has played a leading role. Latin America lacks of a unified environmental policy as a whole. Isolated efforts exist in all the countries. We briefly present at the end of the chapter the initiatives for each of the countries included in the study of LA. Except for the case of Uruguay, -where we didn't find information- we find that the countries have signed international agreements to control pollution. However.

few cooperative efforts exist inside LA countries. This is the main difference regard to EU. Appendix II presents the main environmental initiatives that exist in this group of countries.

For instance, Table N. [1] shows some of the International Environmental Agreements signed by each country in air pollution prevention and control.

Environmental Agreement	Who has signed?
Agreement in Force - Current Status = Party	
Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer (London, 1990)	All
Convention for the Protection of the Ozone Layer (Vienna, 1985)	All
United Nations Framework Convention on Climate Change (New York, 1992)	All
Convention on Road Traffic (Geneva, 1949)	Arg, Chl, Ecu, Par, Peru, Ven
Kyoto Protocol (Kyoto, 1997)	All
Agreement Signed - Current Status = Signatory	
Convention on the High Seas (Geneva, 1958)	Argentina, Bolivia, Colombia and Uruguay

Cuadro 1: International Environmental Agreements signed by LA countries

3. CO_2 Emissions and Energy Use Trends in Latin America

After reviewing Latin America environmental efforts, we see that the group lacks of a unified effort to reduce the use of energy and therefore, the emissions each country produces. Emissions data for LA is only available for CO_2 from the Carbon Dioxide Information Analysis Center (CDIAC). We use CO_2 emissions from fossil fuels in thousand metric tons of carbon. The GDP and population series are taken from the Penn World Tables 6.0. Oil consumption data was taken from the Energy Information Administration (EIA) in thousand barrels per day. The countries included in the panel are: Argentina, Brasil, Bolivia, Chile, Ecuador, Colombia, Venezuela, Mexico, Costa Rica, Uruguay, Paraguay and Peru. Almost all of the LA countries have increased its oil consumption and consequently, its CO_2 emissions.

This is reflected in the trends in energy use and CO_2 emissions. Graphs N. [1] and [2] show that all the countries (except Argentina and Chile) have increased its energy use regard economic activity (GDPpc). Oil barrels per cápita have increased in the last 15 years. There's no available data for the previous years. CO_2 emissions in per capita terms have been increasing steadily since 1950. Figure N. [3] shows both variables over time. For oil consumption we note 1980's international oil price shock influence for the economies, afterwards we see a steady increase in this fossil fuel use for LA.

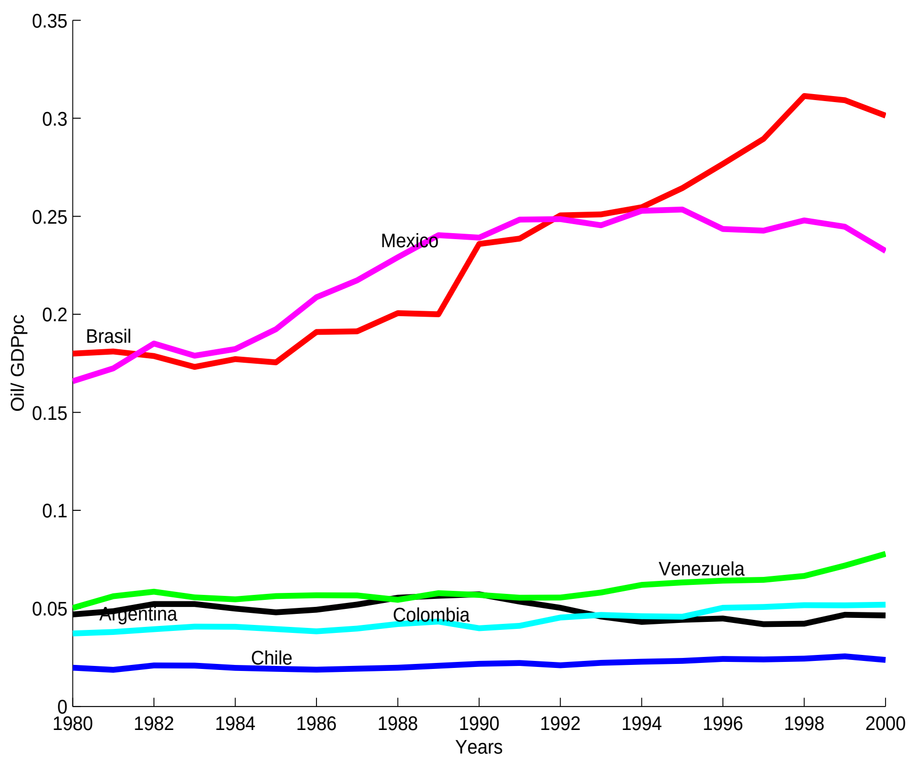

Figura 1: Latin America Oil Barrels / GDPpc.

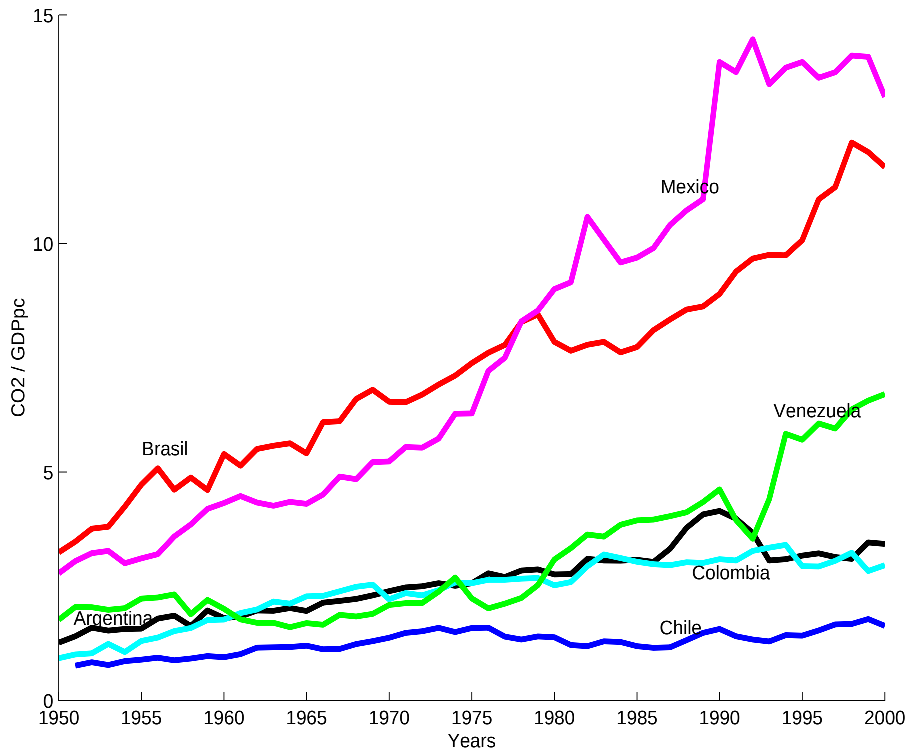

Figura 2: Latin America CO_2 Emissions / GDPpc.

We also find some evidence when we plot crude oil consumption per capita versus CO_2 per capita. Figures N. [4] and [5] present the direct relation that exists between both variables, being polluting emissions a by-product of energy consumption. The correlation coefficients for both variables are $\rho_{1980} = 0{,}9698$ and $\rho_{2000} = 0{,}9057$ for 1980 and 2000 respectively.

The idea is to check, from a statistical point of view, if there has been an environmental evolution in LA countries, where evolution stays for emissions or oil consumption increases or reductions, improvements in the emissions ranking of the countries through time and so on. To this end, we adopt a nonparametric approach above all to seize the advantages of its typical instruments of analysis. In particular, we perform nonparametric tests usually employed to find out the existence of homogeneity between samples and independence among samples char-

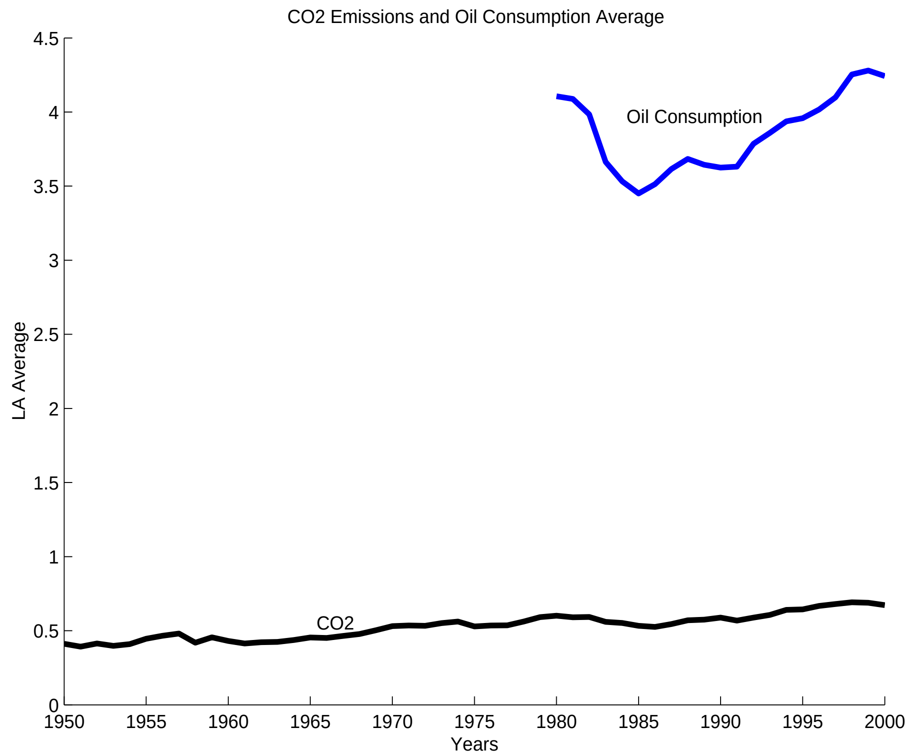

Figura 3: Latin America Oil Barrels and CO_2 emissions per capita averages.

acteristics. For LA we choose two samples, CO_2 emissions per capita and Oil Consumption per capita in 1950 and in 2000 and in 1980 and 2000 respectively, and try to see what kind of changes have happened in this period. The main finding we get is that polluting emissions levels at a LA level have increased from 1950 to 2000. On Appendix III we present the results of the nonparametric approach that we made as a first step to have some intuition about the evolution of energy consumption (crude oil) and the emissions (CO_2) for LA countries for all the period considered.

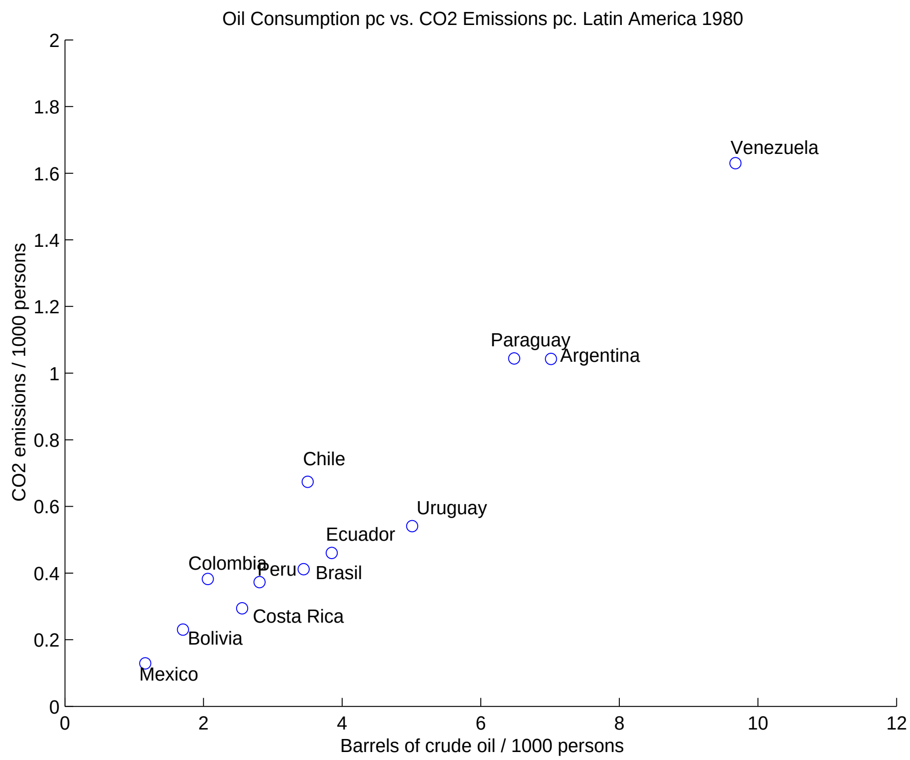

Figura 4: Oil consumption per capita vs. CO_2 emissions per capita. 1980

4. Analysis of Convergence: 1950 - 2000

Our empirical approach to pollution and convergence of emissions starts with a cross-section regression analysis: we adopt the methodology of Barro and Sala-i-Martin[1] largely used in the empirical approach to income convergence. Then we extend the convergence analysis through panel regressions. For CO_2 and oil consumption we give a first evidence of convergence within LA countries

In this analysis we abstract away from the industrial structure of each country. The industrial structure would clearly help to explain the difference across countries in the evolution of the national pollution levels, but here we focus on finding those differences rather than on explaining them.

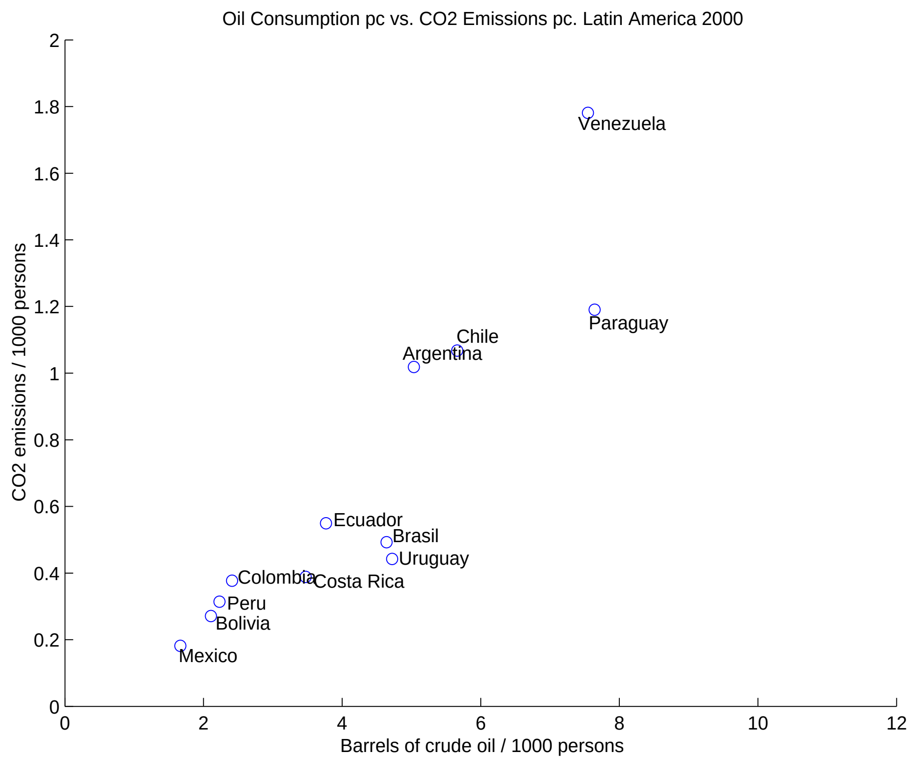

Figura 5: Oil consumption per capita vs. CO_2 emissions per capita. 2000

4.1. Basic Statistics

Table N. [2] reports the basic statistics on growth in per capita income, oil consumption and pollution emissions. Virtually, all countries have steadily increased its CO_2 emissions since 1950. On average, the cross-country annual growth rate has been 1.45 %, 2.49 % and 0.46 % for GDPpc, CO_2 emissions and oil consumption respectively. This suggests an increase in oil consumption and polluting emissions due to economic growth. For instance, CO_2 emissions generation for all LA countries has increased more than the growth in fossil oil consumption. This can be interpreted by the fact that the region is growing. If we have a look to individual countries, Chile is the only country that has larger economic growth than emissions growth. Chile during the last 15 years has made remarkable efforts on its economic development.

On the other hand, Venezuela, Peru, Ecuador, Uruguay and Argentina own the worst performance for all the period: positive CO_2 emissions growth rates but negative economic growth rates.

One way to organize the data for a systematic analysis of cross-country differences can be taken from the literature on convergence and growth. The idea is to evaluate the ability of the convergence hypothesis to explain why some countries have increased emissions faster than others. This hypothesis with pollution data implies that 1950-2000 pollution growth will tend to be directly related to 1950 level of emissions.

As a first step to measure the existence of convergence, we ask whether the countries which started with less per capita pollution levels at the beginning of our sample period, 1950, have achieved, on average, larger increases in their per capita pollution emissions thereafter, up to year 2000. The same criteria applies for oil consumption during the period 1980-2000. For CO_2, the standard approach is to estimate the equation:

$$GCO_{2,i,00-50} = \alpha - \beta \log\left(CO_{2,i,50}\right) + \varepsilon_i \tag{1}$$

and for Oil consumption is

$$GOil_{i,00-80} = \alpha - \beta \log\left(Oil_{i,80}\right) + \varepsilon_i \tag{2}$$

where the subscript i refers to country i, $CO_{2,i,t}$ denotes the (*per capita*) CO_2 in country i at time t, $Oil_{i,t}$ is (*per capita*) oil consumption in country i at time t, $GCO_{2,i,00-50} = \frac{1}{50}\ln\left(CO_{2,i,00}/CO_{2,i,50}\right)$, $GOil_{i,00-80} = \frac{1}{20}\ln\left(Oil_{i,00}/CO_{2,i,80}\right)$ and ε_i is the perturbation error. Whenever β is statistically negative, there exists evidence in favor of the β-convergence hypothesis on 1950-2000 period and 1980-2000 for the case of oil consumption variable. In this case, β measures the rate of convergence towards a *pseudo* steady state [De la Fuente[2]], which has not been necessarily achieved at the end of the sample period.

Figures [6] and [7] show the scatter plot and the fitted line between $GCO_{2,i,00-50}$ and $\log\left(CO_{2,i,50}\right)$ for CO_2 emissions and $GOil_{i,00-80}$ and $\log\left(Oil_{i,80}\right)$ for oil consumption in per cápita measures. In general, the relationship shows a negative slope, but the degree of dispersion varies among the variables. Thus, according to the figures, weaker convergence evidences are shown for Oil Consumption while less dispersion is appreciated for CO_2.

Figures [8] and [9] show the scatter plot and the fitted line between emissions and oil consumption with regard to economic activity (GDP). In this case, it seems to exist less convergence between the countries. The dispersion varies among the countries. Table N. [3] shows the estimations of the coefficients. All the variables show a negative β coefficient, however, they're not statistically significative except for CO_2pc and $Oilpc$ at 95 % and 90 % levels respectively. We reject the null hypothesis $[H_{0,CO_2} = H_{0,Oil} : \beta = 0]$[11] in this case. So for LA countries, we have evidence that convergence exists in CO_2 emissions and Oil in per capita levels. This suggests that initial levels may contribute to explaining why some countries have increased emissions faster than others. Further, the evidence is in favor of absolute convergence within LA. This implies that the initial level of emissions could account for pollution dynamics to a different extent according to observable characteristics.

However, using equations (1) and (2), the estimation of β could be biased because of two main reasons: the omission of relevant variables and the imposition of a common steady state for all countries. To avoid this problem, at least partially, we first extend equations (1) and (2) and controlling for the per capita real GDP growth rate, and next we use a fixed effect model of convergence, using the whole panel information.

Further, one question is whether absolute convergence in pollution if any can be explained by GDP convergence or by a reduction in the dispersion of emission levels across LA economies. For the first part, the estimated β coefficients of the regression above in income variables are included in Table N. [3]. The evidence is not in favor of absolute convergence in GDP for LA. For the σ - convergence analysis the question is whether the cross-country coefficient of variation in emission levels for the year 2000 is smaller than for year 1950. The results in Table [3] show either no evidence of σ - convergence or a mild evidence in line with the β - convergence analysis. This is complemented in Figures [10] and [11] where we observe that LA countries are approximating to it's steady state level.

[11]Alternatively, $[H_{a,CO_2} = H_{a,Oil} : \beta < 0]$

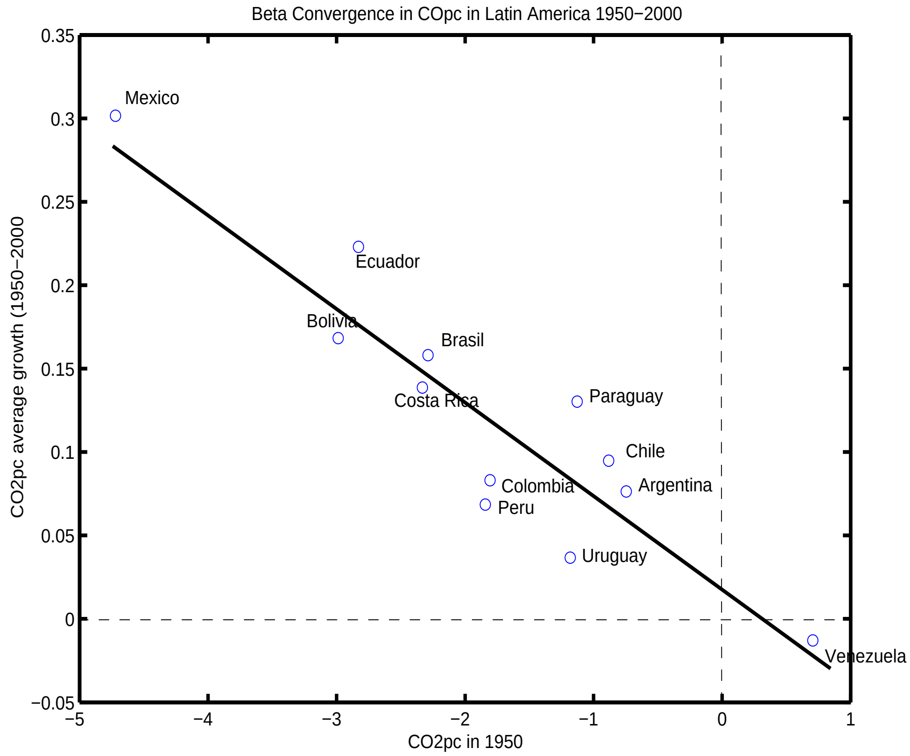

Figura 6: Latin America β Convergence in CO_2 Emissions.

4.2. Cross - section regression

So far we have provided preliminary evidence of faster increase in emissions the higher its 1950 level and oil consumption the higher its 1980 level. There is also evidence that income dynamics do not play a role in pollution dynamics.

The hypothesis of the environmental Kuznets curve (EKC) suggests that the reduction in the pollution per capita level is closely related to the per capita real GDP growth rate over the considered period. In other words, the evolution of pollution emissions of any two countries with the same per capita pollution level at 1950 is expected to be very different to each other if the growth rate of both countries along the sample period have been very different as well. Still, we might go a step further, since EKC suggests that the effect of growth might be

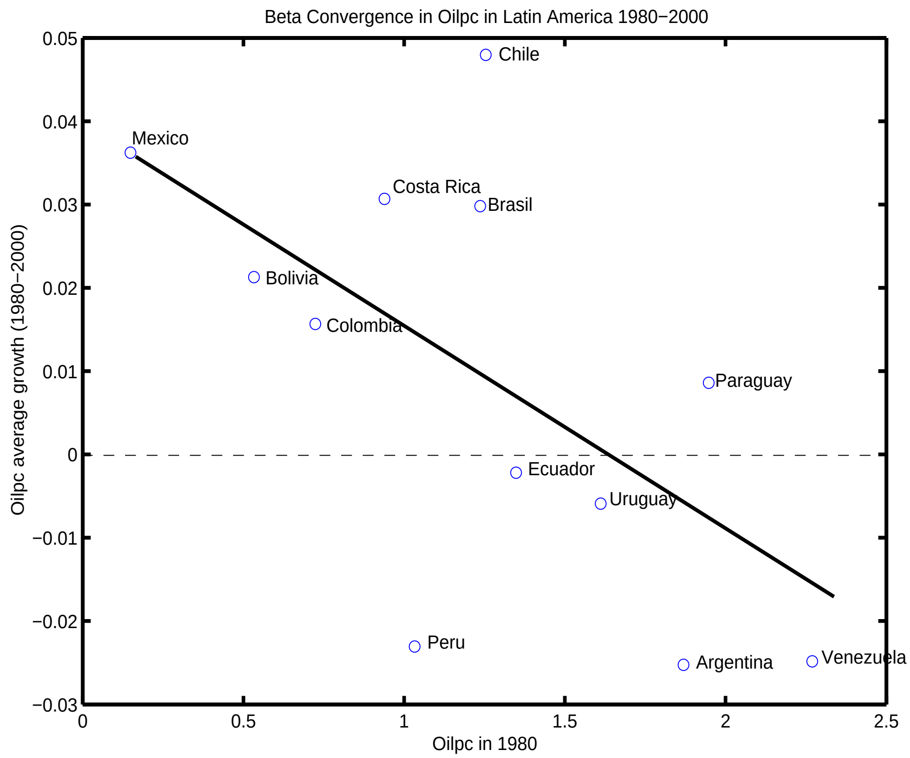

Figura 7: Latin America β Convergence in Oil Consumption.

non-monotonic (in GDP). For that reason, a more appropriate equations would be:

$$GCO_{2,i,00-50} = \alpha - \beta \log CO_{2,i,50} + \phi_1 GGDP_{i,00-50} + \phi_2 \log GDP_{i,50} + \varepsilon_i \quad (3)$$

$$GOil_{i,00-80} = \alpha - \beta \log Oil_{i,80} + \phi_1 GGDP_{i,00-80} + \phi_2 \log GDP_{i,80} + \varepsilon_i \quad (4)$$

where $GDP_{i,t}$ denotes the *per capita* real GDP of country i at time t, $GGDP_{i,00-50} = \frac{1}{50}\log(GDP_{i,00}/GDP_{i,50})$.

Table N. [4] shows the OLS estimation results of equations (3) and (4) for the variables.

Essentially, the hypothesis of the existence of β-convergence ($\beta < 0$) cannot be rejected for any variable at usual significance levels. In

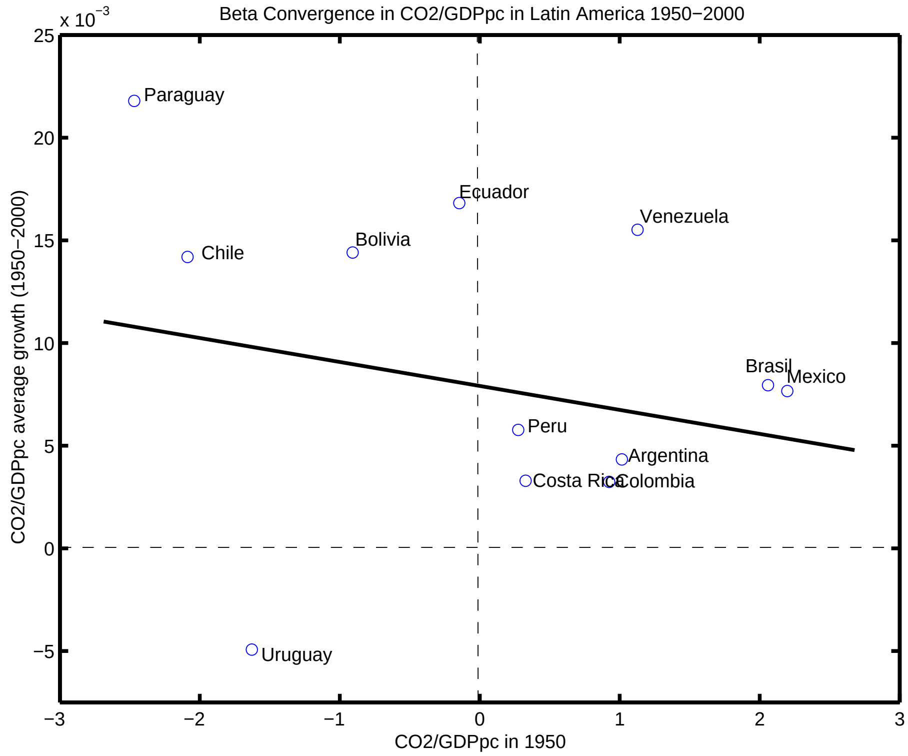

Figura 8: Latin America σ Convergence in CO_2 Emissions.

relation to equations (1) and (2), the significativeness of the β is now higher.

In addition, we must mention that the estimated value for ϕ_2 and ϕ_1 in equations [3] and [4] is not statistically different from zero for CO_2 emissions while for the case of oil consumption, GDP per capita growth during the period 1980-2000 is a relevant variable. Table N. [4] shows the results of the estimations. We call the new coefficient *corrected* β.

The residuals of the previous estimation have an interesting interpretation. Let us pose a simple question: which countries have done environmentally well in our sample period? At first sight, we might say: those who have achieved reductions in their pollution level. But clearly, we immediately would like to add some qualifications to our previous sentence, like to allow for a smaller reduction before labeling a country as *dirty* if, in change, the country has grown very fast, or if

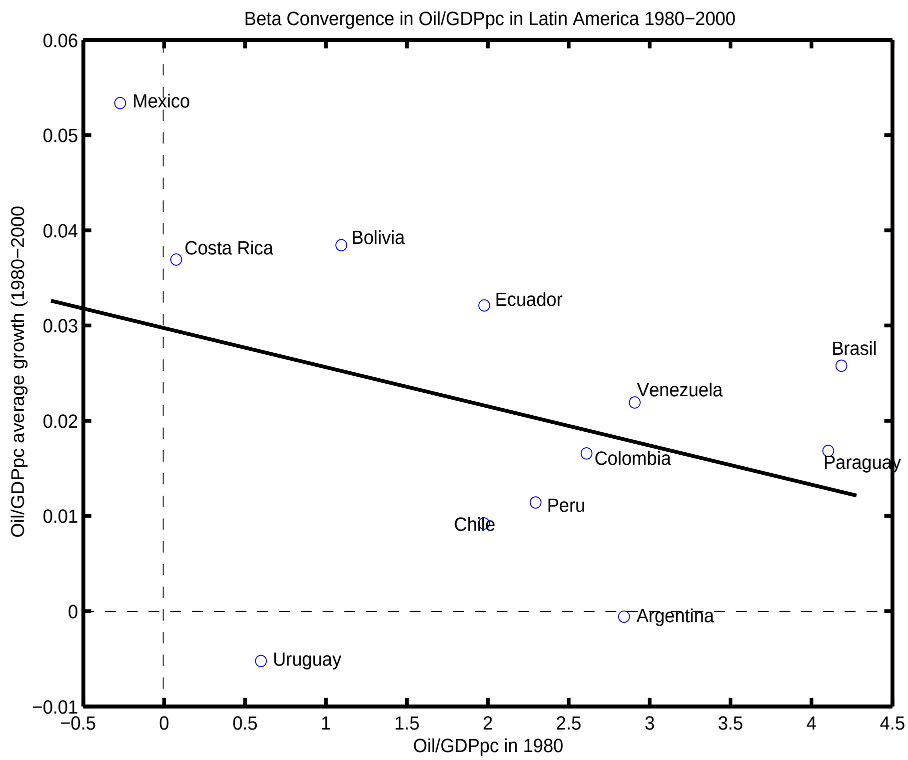

Figura 9: Latin America σ Convergence in Oil Consumption.

the country has started from a small pollution level. A negative residual in the estimation of eqs. [3] and [4] indicates that the corresponding country has reduced its pollution level beyond what is expected for its growth rate and initial pollution level, that is a *clean* country. Alternatively, we associate a positive residual to a *dirty* country. Figures N. [12] and [13] show the residuals for each country and variable, measured in standard deviation units. For the case of oil consumption, the countries that have reduced its fossil fuel consumption are Argentina, Colombia, Peru and Uruguay while the rest of the countries have increased it. For CO_2, the çleanestçountries are Brasil, Costa Rica, Colombia, Peru and Uruguay. The latter countries even if the have been growing during the last 50 years, they have decreased it's fuel consumption but their CO_2 emissions are still growing.

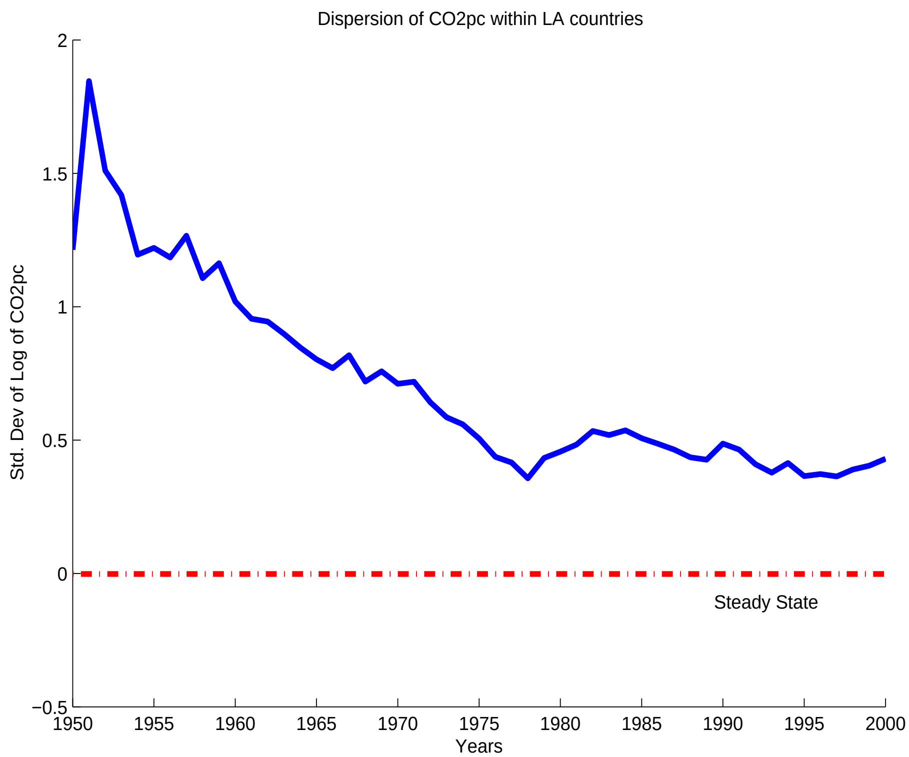

Figura 10: σ Convergence in CO_2 Emissions in LA.

4.3. Panel data analysis

In the previous convergence model, we do not take into account the yearly evolution of the pollution levels within the sample period. However, as it is well known, this yearly evolution might help us to predict what we expect for the future. In addition, regarding pollution emissions, we appreciate an important heterogeneity among LA countries considered, which suggests the advisability of a closer look into smaller units. For instance, not all of the countries play a similar role in the region, depending on factors like the economic structure, institutions, population, etc., it would be expected that each economy would be converging towards different steady states. Moreover, as it is pointed out by Selden and Song[8], emissions are measured imperfectly and errors for a country persists over time. All these factors reinforce the use of

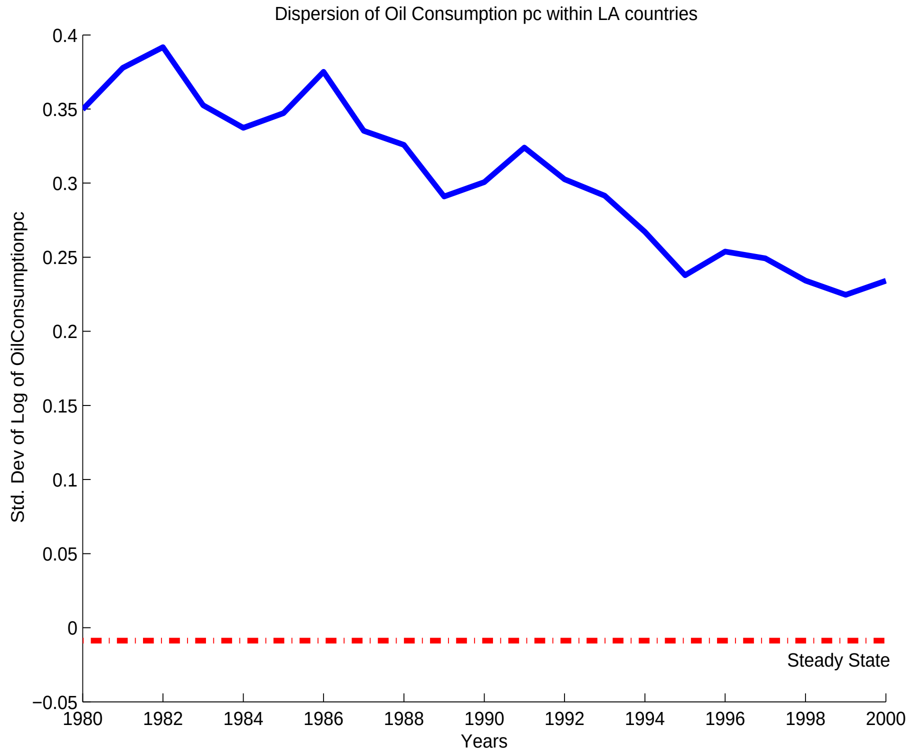

Figura 11: σ Convergence in Oil Consumption in LA.

panel data techniques to deal with convergence issues in a heterogenous set of countries.

We specify a panel data model with fixed effects[12]. Typically, the kind of equations that accounts for yearly evolution are:

$$GCO_{2,i,t} = \alpha_i - \beta \log(CO_{2,i,t-T}) + \psi_1 GGDP_{i,t} + \psi_2 \log GDP_{i,t-T} + \upsilon_{i,t}, \quad (5)$$

$$GOil_{i,t} = \alpha_i - \beta \log(Oil_{i,t-T}) + \psi_1 GGDP_{i,t} + \psi_2 \log GDP_{i,t-T} + \upsilon_{i,t}, \quad (6)$$

[12] An homogeneity F -residual test suggests the use of a model in which the parameter á is country dependent. The Haussman test does not reject the fixed effect model hypothesis. We use non-linear least squared method to implement the restriction on parameters. All inference is based on the White heteroskedasticity-consistent covariance matrix.

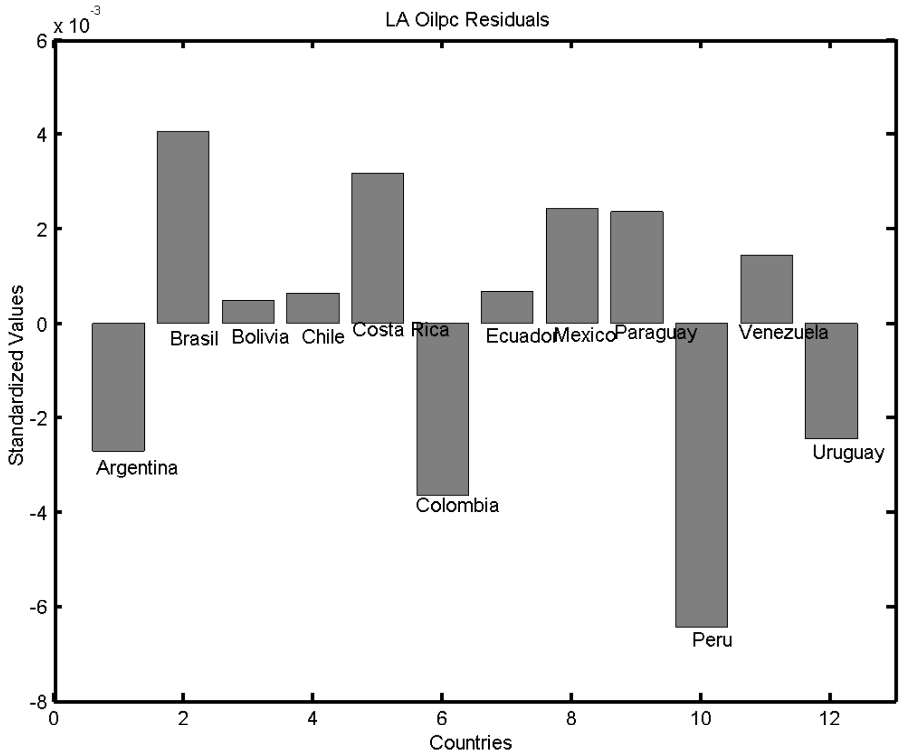

Figura 12: Oilpc estimation residuals

where $GX_{i,t}$ is the difference operator for any variable X, i.e., $GX_{i,t} = \Delta \log X_{i,t} = \log(X_{i,t}) - \log(X_{i,t-1})$. If $|1+\beta| < 1$, the convergence equation suggests that the variable is converging towards a pseudo steady-state, defined by $\Delta \log(X_{i,t}) = 0$, or equivalently, $\log(X_{i,t}) = \alpha_i/\beta$, for all t, which would be characteristic for each country if the α_i differs among countries. α_i captures the inherent - and time invariant - heterogeneity in pollution emissions among countries that is not explained by the income growth average and the average level of income. The closer β to 1, the faster the convergence process.

The diagnosis stage showed significant positive residuals (on average for all countries). There are a number of factors, like technological changes and the impacts of environmental regulation, that might cause that residuals of the regression to be systematically positive. We want to estimate eqs. N. [5] and [6] without regard to these latter factors. Ta-

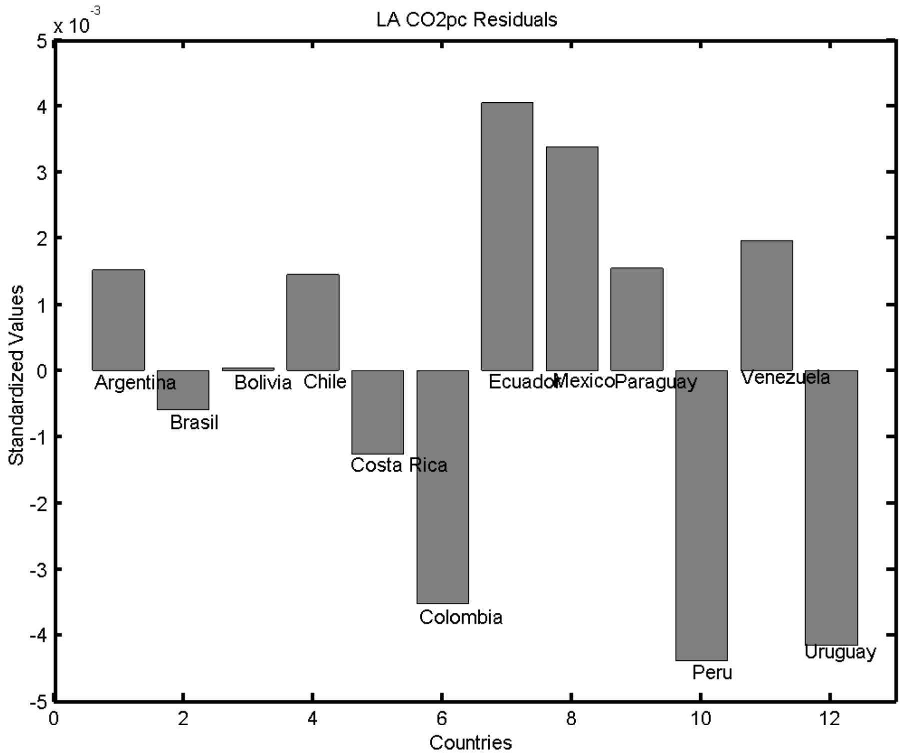

Figura 13: CO_2pc estimation residuals.

ble N. [5] summarizes the estimates from the fixed effect model for oil consumption and CO_2. These estimates are computed over the whole set of countries. As can be seen from the estimations, the pollution level has a significant positive effect on the rate of decline of emissions.

The effect of the output growth rate on CO_2 emissions and oil consumption growth rates is always positive and statistically significative. However, the estimates of the ψ's in the table could suggest substantial differences according to the country considered. Studying those issues goes beyond these paper.

We use OLS method for pooled regressions. However, an anomalous behavior of a particular country might bias the estimation of common coefficients. Thus, we also use a GLS, cross section weighted, estimation method. Inference exercises are based on the White heteroskedasticity-consistent covariance matrix.

The table shows that the estimated β's stay within the interval $(-1, 0)$ for CO_2 and Oil Consumption and they are statistically different from zero at 1 % significative level. These results reinforce the evidence in favor of accepting β-convergence within LA countries in terms of pollution emissions and oil consumption. The countries are slowly coverging toward their *pseudo* steady states. There is a statistically different from zero relationship between GDP and pollutant growth and oil consumption.

There exists evidence of convergence and a monotonic relationship between the degree of pollution and the degree of development (consistent with the EKC).

5. Final Comments

Data on pollution from the CDIAC reveals that polluting and oil consumption intensities had increased over the second half of the twentieth century in most LA countries.

The goal of the paper was threefold: first, to give a qualitative and quantitative measure on the degree of convergence in pollution emission and oil consumption within a set of LA countries along this period; second, to classify these countries according to its relative position in terms of pollution emission; third, to relate the evolution of emissions with the growth rate experienced along the fifties.

We focused on alternative convergence equations, applied to a cross section of LA countries and to the whole panel information, to explore these issues.

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6. Appendix I

6.1. Statistical results

We use two paired samples, for instance A and B; that is, for all LA countries, we consider the variable measure under examination in 1950, 1980 and 2000. We always refer to such samples in this analysis. Here we report the results of all the tests done. We have performed 3 different nonparametric tests: Wilcoxon, Spearman and τ - Kendall.

The Wilcoxon test permits to explore the same issue as before. The statistics are $T+$, $T-$ and the sum of these two, T. The first one is the sum of the ranks of assigned to the "positive"differences between each couple of observations, the second one is the sum of the ranks assigned to the "negative"differences . When the two samples are homogeneous, differences between each couple of corresponding observations not only are uniformly distributed among positive and negative values, but also their magnitudes are distributed in a symmetric way. Usually when sample size is greater or equal than 25, the Standard Normal approximation of $T+$ is used. Anyway, even if our sample size is smaller than 25, we still use the Standard Normal approximation to do the test. As it is shown in Table N. [6], we always reject H_{0,CO_2}: LA countries have decreased the CO_2 emissions but we can't reject $H_{0,Oil}$: LA countries have decreased Oil consumption per capita. Both at the usual levels of significance. We reach this result not only using the Normal approximation, but also comparing $T+$ with the critical values presented in the Wilcoxon specific table. Looking at the different magnitudes of the two statistics, T + and T -, (see again Table N. [6]), it is obvious that the distribution of the differences between each couple of variables is not symmetric in the case of CO_2 but it is in the case of Oil Consumption. So the statistical results show that emissions have ïncreased"from 1950 to 2000 and that oil consumption has "decreased"during the last twenty years. As a matter of fact, five of the twelve countries considered showed a fall of the fossil fuel between 1980 and 2000. Nevertheless, the methodology is not perfect and the results could be distorted due to the years considered.

To answer the second question, we start with Spearman test. A sort of correlation coefficient, r_s , is calculated, then a "t"statistic is obtained and compared with the critical value of the corresponding table. The coefficient r_s can take values between -1 and 1, as any correlation coefficient; when $r_s \approx 1$, a direct relation among the two samples exists while in the case of $r_s \approx -1$, such relation is inverse. Finally, when the value of the coefficient is near zero, no relation exists. When H_0 is true, ranks of the countries in 1980 and 2000 are independent and this result is supported by a value of the coefficient near zero. As it is clear from Table N. [6], we reject H_0 in CO_2 and Oil Consumption. There exists a relation among the two samples; the magnitude and, above all, the sign of r_s suggest the existence of a direct relation: in other words, it seems that at high values of the variables in 1950 correspond high values in 2000 and the same is true for low values (the relative position of the members has not changed).

Also in the t - Kendall test, a sort of correlation coefficient is computed, τ, and it takes the usual values $-1 \leq \tau \leq +1$. For sample size greater or equal than 10, it is common to use the Standard Normal approximation. The previous coefficient applies also to this case. Looking at Table N. [6] , it is obvious that H_0 is always rejected. The sign of the coefficient is positive, implying a direct relation among the samples, that is LA countries ranking does not seem to have changed from 1950 to 2000.

6.2. Conclusions

According to the questions formulated in the text, the statistical results lead us to the following conclusions:

1. LA countries have increased it's CO_2 polluting emissions (Wilcoxon results);

2. LA countries have decreased Oil consumption (Wilcoxon results)?

3. Relative positions in the emissions ranking have not changed (Spearman, t - Kendall results)

These results are quite in line with our initial intuition about the emissions performance of LA countries, especially taking into account the heterogeneity of the countries. Even if emissions have increased, members positions according to the quantity of pollution produced, have not changed. At the same time, it is crucial to remember that LA members have quite different economies, population levels, geographical extensions. A further analysis going through such heterogeneity, could help to better understand the above conclusions.

	GDPpc			CO_2			Oil Consumption		
	1950	2000	A.Growth	1950	2000	A. Growth	1980	2000	A. Growth
Argentina	6430	11006	1.08	0.5449	1.0184	1.54	6.4830	5.0358	-1.25
Brasil	1655	7190	2.98	0.1080	0.4925	3.21	3.4438	4.6400	1.50
Bolivia	2749	2724	-0.018	0.0456	0.27	3.4236	1.7040	2.1081	1.07
Chile	3367	9926	2.18	0.4135	1.0675	1.91	3.5036	5.6604	2.43
Costa Rica	2483	5870	1.75	0.1018	0.3883	2.81	2.5569	3.4748	1.55
Colombia	2208	5383	1.8	0.1745	0.3771	1.67	2.0619	2.4117	0.79
Ecuador	1637	3468	1.51	0.0590	0.5492	4.56	3.8512	3.7677	-0.11
México	2990	8762	2.17	0.3584	1.1902	2.64	7.0131	7.6434	0.43
Paraguay	2412	4684	1.36	0.0089	0.1818	6.22	1.1604	1.6668	1.83
Perú	2488	4589	1.23	0.1613	0.3142	1.38	2.8085	2.2302	-1.15
Venezuela	5908	6420	0.17	2.4077	1.7813	-0.26	9.6746	7.5463	-1.23
Uruguay	5278	9622	1.21	0.3227	0.4423	0.74	5.0103	4.7225	-0.3
Mean	3300	6637	1.45	0.3922	0.6728	2.49	4.106	4.2423	0.46
Std Dev	1643	2683	0.83	0.6561	0.4835	1.74	2.513	2.021	1.271

Cuadro 2: Cross-country comparison: per capita GDP, Oil Consumption and Pollution Emissions (1950-2000)

	CO_2pc	$\frac{CO_2}{GDP}$	Oilpc	$\frac{Oil}{GDP}$
α	0.0268	0.0009	0.037	0.0299
	(0.7399)	(4.0467)	(2.6235)	(3.7478)
β	-0.0519	-0.00127	-0.0228	-0.0041
	(-6.7678)	(-0.7967)	(-1.9800)	(-1.1278)
$Cov_(GX_{i-T}, X_i)$	-0.0971	-0.003	-0.0087	-0.0087
$\rho_(GX_{i-T}, X_i)$	-0.9147	-0.2861	-0.6086	-0.3883
R^2	0.8367	0.081	0.3701	0.1507

Cuadro 3: Cross-section regressions of Oil Consumption (1980-2000) and Pollution Emissions (1950-2000) growth rates. t statistic in parenthesis

	$\Delta CO_2pc5000$	$\Delta Oilpc8000$
α	-0.003	0.0345
Corrected $- \beta$	-0.0113	-0.0083
	(-7.2234)	(-2.7814)
$\log GDP_i$ - ϕ_2	0.0008	-0.0077
	(0.1098)	(-1.0989)
$GGDP_{i-T}$ - ϕ_1	0.2619	0.6502
	(1.1938)	(6.7479)
R^2	0.8505	0.6723

Cuadro 4: Cross-section regressions of Oil Consumption (1980-2000) and Pollution Emissions (1950-2000) growth rates. t statistic in parenthesis

	Fixed Effects		**GLS**	
	$\Delta CO_2pc5000$	$\Delta Oilpc8000$	$\Delta CO_2pc5000$	$\Delta Oilpc8000$
$logX_{i,t-T} - \beta$	-0.1052	-0.1670	-0.1495	-0.1118
	(-7.5974)	(-4.3043)	(-4.2911)	(-7.4080)
$\Delta GDP_{i,t}$ - ψ_1	0.4998	0.6358	0.5868	0.5046
	(5.6868)	(7.6189)	(9.1709)	(8.0685)
GDP_{i-T} - ψ_2	0.0964	0.2232	0.1800	0.0915
	(4.2740)	(4.4639)	(4.5160)	(5.0060)

Cuadro 5: Panel estimations with fixed effects for Oil Consumption (1980-2000) and Pollution Emissions (1950-2000). t statistic in parenthesis

	CO_2	Oil Consumption	$GDPpc$
	Wilcoxon		
Statistic (normal)	-2.589	-0.706	-2.981
Significance value	0.010	0.480	0.003
Positive ranks	11	7	11
Negative ranks	1	5	1
Sample	12	12	12
	Spearman		
Correlation	0.790	0.916	0.622
T	4.078	7.224	2.514
Significance value	0.002	0.000	0.031
	τ- Kendall		
Coefficient	0.606	0.788	0.424
T	3.802	9.390	2.119
Significance value	0.000	0.000	0.034

Cuadro 6: Non Parametric Tests Results