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GDP and environment pressure: The role of energy in Latin America and the Caribbean

Mariana Zilio, Marina Recalde*

Departamento de Economía, Universidad Nacional del Sur, Instituto de Investigaciones Económicas y Sociales del Sur (IIESS) Consejo Nacional de Ciencia y Tecnología (CONICET), Argentina

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ABSTRACT

This paper analyzes the relationship between economic growth and energy consumption for a sample of 21 Latin American and Caribbean countries during the 1970–2007 period. The investigation is made on the bases of the Energy Environmental Kuznets Curve (EEKC) hypothesis, using a panel data analysis. Energy consumption at aggregate level is used as an indicator of human environmental pressure and GDP per capita as an indicator of economic activity. Based in a cointegration approach, our results does not support the existence of a stable long run relationship between the series, rejecting the validity of such hypothesis for the selected sample over the 1970–2007 period.

1. Introduction

The relation between environment and economic growth has been widely explored in economic theory. However, empirical analysis boosted in the early 1990s, as a result of the availability of environmental data and more sophisticated econometric tools. In this framework, Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992), Panayotou (1993) and Selden and Song (1994), among others, found an inverted U-shaped pattern relation between per capita income and some indicators of environmental degradation, instead of a fixed one. In this frame, emerged the hypothesis of the Environmental Kuznets Curve (EKC), named that way by Panayotou (1993). This hypothesis proposes a long run relationship between economic growth and several environmental degradation indicators. The basic notion behind this hypothesis is that resource use increases, worsen environmental degradation, during the early stages of development, and decreases in later stages followed by improvements in environmental quality (Rothman, 1998).

During the last decades, the interest in global warming has inspired the study of the driven factors of greenhouse gases (GHG) emissions. Different studies emphasize that these emissions are mainly due to energy, transportation and industry sectors (World Resources Institute, 2009; IEA, 2010). Therefore, there may be a relation between EKC and energy and then it can be used as an indicator of environmental pressure in different regions of the world.

In this frame, the main objective of this paper is to study the relation between GDP and energy consumption in Latin American and Caribbean countries (LA&C), in order to discuss energy environmental pressure of economic growth. Our purpose is to contribute to the current environmental and energy policy discussion. Thus, we seek to determine whether there is a clear relation between both variables or not and, in case it exists, if this relation displays an inverted U-shaped pattern, as marked by the EKC hypothesis. Policy implications of this study are straightforward. If there is not an inverted U-shaped relation, energy and environmental policies will be required in order to mitigate energy consumption growth and its environmental pressure. Conversely, if this relation exists two situations are possible attending to the per capita income of each country regarding the turning point. For countries located on the right side of the turning point higher per capita income corresponds to lower energy use, precisely because they have applied more energy efficiency policies. For countries on the left side, policy makers decision is twofold, they can either decide to promote energy efficiency, or wait and grow according to Beckerman's argument discussed below.

Therefore, we perform an empirical study to test the validity of EKC hypothesis for energy consumption, for a sample of LA&C countries over the 1970 and 2007 period. The study begins with a brief review of the theoretical and empirical literature on EKC hypothesis. Then we assert that energy consumption is one of the main driving forces behind environmental impact and summarize the recent evolution of worldwide energy consumption. Before performing the empirical analysis we briefly describe the econometric methodology, panel unit root and panel cointegration

* Correspondence to: IIESS—UNS-CONICET, 12 de Octubre y San Juan piso 7, B8000CTX Bahía Blanca, Argentina. Tel.: +54 0291 4595138; fax: +54 0291 4595138.
E-mail address: mrecalde@uns.edu.ar (M. Recalde).

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tests, and highlight the main economic and energy characteristics of sample. Finally we discuss our results.

2. Literature review

From the early 1990s, and after both papers of Grossman and Krueger (1991) and Panayotou (1993), the discussion over the relation between environment and economic growth has been mainly developed around the EKC, named this way for Kuznets (1955), who hypothesized that income inequality first rises and then falls as economic development proceeds (Stern, 2004).

The EKC asserts the empirical existence of an inverted U-shaped relationship between environmental degradation and economic growth. This hypothesis implies that environmental damage increases with economic activity, up to a certain level of income also called turning point, after which income increases are associated to higher environmental quality. Therefore, the key point behind the idea is that environmental pressure increases faster than income in the early stages of development and slows down (in relation to GDP growth) in higher income levels (Dinda, 2004).

As stated by Galeotti et al. (2006) the inverted U-shaped of the curve contains a powerful message: gross domestic product is both the cause and the cure of the environmental problem. Furthermore, if this hypothesis were unambiguously true, Beckerman's argument would be valid, and the best, and probably the only way to improve environmental quality would be countries to become richer (Beckerman, 1992). An implicit assumption on this assertion is that economic growth will generate the technology transfer required to reach a higher environmental quality. Moreover, this assumption implies that time is the only obstacle to achieve such technology transfer. However, it seems to be evident that green technologies spillover is no automatic in any case and also faces technical, institutional and social obstacles, mainly in developing countries.

Theoretically, there are multiple reasons to explain the change on the shape of the curve.[1] Income elasticity and other characteristics of environmental quality demand have been–and still are–the most important and simplest explanations for the EKC functional form (Selden and Song, 1994; Beckerman, 1992).The argument is based on the idea that the poorest sectors of society will not demand environmental improvements as far as not covering other basic needs, such as nutrition, education or health care. Nevertheless, it is natural to think that once individuals have reached a certain level of life; they will demand higher value of environmental goods and services, raising their willingness to pay in larger proportion to income growth (Roca, 2003).

Another important set of EKC explanations includes changes in productive structures and the effects of growth process over environmental conditions defined by Grossman and Krueger (1991) in its work about environmental impacts of the North American Free Trade Agreement: scale effects, composition effects and technology effects.

Scale effects arise as more economic activity implies more wastes, more pollutant emissions and higher environmental damage. In other words, scale effects may be interpreted as the environmental degradation required for sustaining the growth process.

Simultaneously, as income grows the economic structure changes, increasing the share of less environmentally damaging activities. Clearly, transition from rural to industrial activities produces higher environmental degradation, however through the industrialization process the economy evolves to a higher development stage. This phase shift causes another structural change to an economy based on services, clearly less polluting than industrial activity. In this way, these composition effects generate a positive impact on environmental conditions: income increases after a threshold, entails changes in the structure of the economy and generates improvements in environmental quality.

The third effect defined by Grossman and Krueger (1991) is also positive for environment, and may explain the negative slope of EKC after the turning point as much as the composition effects. Usually, a wealthy nation can afford more R&D investments. Therefore, as a result of these investments, technological progress emerges and dirty technologies may be replaced by cleaner ones. The higher the levels of income per capita, the greater the environmental quality gained through technological improvements.

Hence, the widespread idea that economic development and environmental quality are incompatible goals only reflects the scale effect (Stern, 2004). Nevertheless, it is possible that the negative effect on environment caused by economic growth is offset by the composition and technology effects only once the early stages of growth have been exceeded (Vukina et al., 1999).

International trade constitutes another usual explanation to the EKC slope (Arrow et al., 1995; Stern et al., 1996; Dasgupta et al., 2001). Its effect on environmental quality results ambiguous because of the interaction of the three (Grossman and Krueger, 1991) effects combined with the possibility of 'export' and 'import' environmental damage embodied in trade flows.

However, in spite of the several arguments in favor of the EKC hypothesis, there are no reasons to suppose that the relationship achieved between per capita income and environmental quality automatically verifies (Bimonte, 2002). For this reason, economic growth would not be a perfect substitute for environmental policy (Arrow et al., 1995).

That means that other relevant factors affect environmental quality and should be included as explanatory variables into the relationship between growth and environment. Moreover, such factors diverge, not only among groups of countries, but also among countries in the same group. For that reason, recent papers have incorporated new determinants to the traditional explanations to EKC. Particularly, some authors included aspects related to income distribution, because of its relevance to understand the relationship between growth and environmental pressure on developing countries (Panayotou, 1997; Magnani, 2001; Bimonte, 2002).

In this frame, the empirical evidence over the validity of EKC is not conclusive (Selden and Song, 1994; Grossman and Krueger, 1995; Stern and Common, 2001; Perman and Stern, 1999, 2003; Stern, 2004). Dasgupta et al. (2002) present an exhaustive criticism about the EKC hypothesis. They assert that the relation between environmental degradation and economic growth is monotonically increasing. While the inverted U-shaped functional form may verify for more controllable pollutants, their reductions are compensated with higher emissions of new toxics which arrive to replace them. Harbaugh et al. (2002) assert that the evidence in favor of an inverted U-shaped relation is not robust. They found that "the locations of the turning points, as well as their very existence, are sensitive to both slight variations in the data and to reasonable permutations of the econometric specification" (Harbaugh et al., 2002; p. 2). In the same direction concludes Magnani (2001), who points out that empirical evidence supporting EKC, crucially depends on the selected pollutant, the sample composition and the period considered.

For these reasons, the election of the indicator of environmental degradation becomes a controversial point, because different indicators may lead to different conclusions on EKC validity.[2]

[1] For an exhaustive survey about theoretical support of EKC hypothesis see Dasgupta et al. (2002) and Dinda (2004).

[2] As Jha and Bhanu Murthy (2003) affirm, it is possible that relating per capita income to particular pollutants only leads to partial conclusions, mainly because many pollutants are related to each other and to other indicators of environmental damage. Nevertheless, almost the all empirical evidence on EKC analyses

In fact, while the inverted U-shaped relationship seems to verify for some specific pollutants (Shafik and Bandyopadhyay, 1992; Grossman and Krueger, 1995; Roca Jusmet and Padilla Rosa, 2003), the study of carbon dioxide (CO_2) shows that the relationship between emissions and per capita income is monotonically increasing (Ravallion et al., (2000); Neumayer, 2004; Azomahou et al., 2006) rejecting the inverted U-shaped pattern.

For that reason, empirical studies over EKC embrace a wide range of environmental degradation indicators. Despite the fact that the analysis of pollutant emissions has widely predominated for many decades, recently the interest over the relationship between economic growth and energy consumption has increased (Suri and Chapman, 1998; Agras and Chapman, 1999; Stern and Cleveland, 2004; Richmond and Kaufmann, 2006; Luzzati and Orsini, 2009, among others).

The first set of studies that use energy consumption as indicator of environmental pressure includes the papers of Suri and Chapman (1998) and Agras and Chapman (1999). The former analyzes the relationship between per capita income and energy consumption, including the effects of international trade as a transmission channel of environmental damage. Their results show that international trade of manufactured goods has a structural and important effect on per capita energy consumption and, thus, on environmental quality. The latter includes energy prices and other factors related with trade in order to test the EKC hypothesis to per capita energy consumption- per capita income and CO_2 emissions-per capita income relationships. In both cases, they found no significant evidence supporting EKC existence concluding that "wait and grow" seems to be an inconvenient solution to environmental problem.

Following this line, the next sections expose the reasons for energy consumption to become relevant as an environmental pressure indicator.

3. Energy consumption: impact and evolution

There are two main reasons for the analysis of the energy EKC. The first reason is the link between energy consumption and economic growth, higher economic growth implies higher energy consumption (Halicioglu, 2009), directly related to the "biophysical constraints" of economic growth (Georgescu-Roegen, 1971). This is because energy supply imposes boundaries to GDP as a result of the role of energy in the production process, the no reproducibility of energy resources, boundaries to within substitution, and limits to the substitution of other factors of production by energy (Cleveland, 2003; Stern, 2004; Beaudreau, 2005). As stated by Acaravci and Ozturk (2010) this has lead to an extensive number of works to assess empirical evidence testing granger causality and cointegration models, which still have not get to clear results (Asafu-Adjaye, 2000; Oh and Lee, 2004; Lee, 2005; Soytas and Sari 2003; Francis et al., 2007; Zachariadis, 2007; Sari and Soytas 2007; Ozturk, 2010; Belke et al., 2011).

The second, and probably the strongest reason to perform energy EKC studies is the link between energy consumption and environmental pollutants. According to the European Environment Agency (2009), power and heat production are the main sources for CO_2 emissions and SO_2, while energy sector is the second source, after transport, for emissions of NO_x. However, as shown in Table 1, energy consumption may be responsible for 77% out of total CO_2 emissions, since every economic activity requires direct or indirect consumption of fossil fuels, heat or electricity to be performed. Therefore, for instance, emissions related to transport are somehow linked to energy use, as they are the result of burning fossil fuels derivates. Nevertheless, it is worth noting from the table that there are other sectors determining global GEI emissions, as well as the CO_2 and other pollutants emissions path could be very different.[3] Moreover, it is important to clarify that, in spite of the high relevance of energy use in climate change emissions, there are other factors crucially affecting environmental pressure.

A crucial point that comes across from Table 1 is the importance of the composition of the energy mix in energy environmental impact, whose relevance may in some cases exceed the energy use one. CO_2 emissions are the result of the burning of fossil fuels, therefore the higher the share of fossil fuels in energy mix, the higher the environmental damage. The International Energy Agency (IEA) (2010) states that during 2008, 43% out of total CO_2 relied on coal, while 37% and 20% were due to oil and natural gas, respectively (IEA, 2010). Thus, the composition of the energy mix and the inter fuels substitutions (within substitution) have played a crucial role in both worldwide energy intensity and environmental pressure reductions (Cleveland, 2003; Stern, 2004). According to Stern (2004) the reduction in energy intensity, one of the main reasons for the decrease in CO_2 emissions, has been due to within substitution, changes toward industries lower energy intensive, and energy policies developed to promote clean technologies and energy efficiency. Furthermore, substitution within primary energy sources leads to reductions on final energy consumption, due to the use of more efficient energy fuels, instead of as a result of changes in energy patterns (Kaufmann, 1992; Cleveland et al., 1984). Therefore, the historical composition of energy mix plays a crucial role on energy intensity and environmental pressure (Stern, 2004). Besides, while developed countries changed their energy mix trough the introduction of more efficient renewable fuels (wind, geothermal, solar, etc.), underdeveloped countries, and particularly poor countries, are still highly dependent on traditional biomass (wood).

Fig. 1 shows the changes in the composition of primary energy balance between 1973 and 2006 for different regions of the world. Fossil fuels remain as the most important resources in world energy mix. They are more important in OECD than in LA&C countries, even when the former made a larger reduction of fossil fuels than the later. It is important to highlight that the share of renewable energy in the energy mix is very different between both regions. Hydro energy is more important for LA&C than for OECD, accounting for 9% and 2%, respectively. Similarly, Combustible Renewable and Waste (CR&W) are also more important for LA&C. However, CR&W has a wide definition,[4] which includes wood and vegetable waste as long as liquid biomass and biogas. The share of each of these sources on CR&W for each region is considerably different. Thus, while in LA&C most of CR&W are solid traditional biofuels and biomass such as wood, animal materials/wastes, domestic refuse, charcoal, agricultural waste, raw materials and probably a small share of first generation

(*footnote continued*)
particular pollutants, probably due to problems inherent to the construction of a more complete and global indicator of environmental degradation.

[3] The study of the evolution of the CO_2 and global emissions, as their relation, is out of the scope of this paper.

[4] According to the IEA "Combustible renewables and waste comprises solid biomass, liquid biomass, biogas, industrial waste and municipal waste. Biomass is defined as any plant matter used directly as fuel or converted into fuels (e.g. charcoal) or electricity and/or heat. Included here are wood, vegetal waste (including wood waste and crops used for energy production), ethanol, animal materials/wastes and sulfitelyes. Municipal waste comprises wastes produced by the residential, commercial and public service sectors that are collected by local authorities for disposal in a central location for the production of heat and/or power".

Table 1
World Greenhouse Gas Emissions.
Source: Own elaboration based on World Resources Institute (2009).

Sector	Share (%)	Final use/activity	Share* (%)	Gas	Share (%)
ENERGY					
Transportation	14.3	Road	10.50	**Carbon dioxide (CO_2)**	**77**
		Air	1.70		
		Rail, ship and other transport	2.50		
Electricity and heat	24.9	Residential buildings	10.20		
		Commercial buildings	6.30		
		Unallocated fuel combustion	3.80		
Other fuel combustion	8.6	T&D losses	2.10		
		Coal mining	1.60		
Fugitive emissions	4.0	Oil/gas extraction, refining and processing	6.40		
Industry	14.7	Iron and steel	4.00		
		Chemicals	4.10		
		Cement	5.00		
Industrial processes	4.3	Other industries	12.00		
Subtotal sectors	**70.8**	**Subtotal uses**	**70.20**		
Land use change	12.2	Deforestation	11.30		
		Afforestation	−0.40	**HFCs, PFCs, SFe**	**1**
		Harvest/management	1.30		
Agriculture	13.8	Agriculture soils	5.20	**Nitrous oxide (N_2O)** **	**7**
		Agricultural energy use	1.40	**Methane (CH_4)** ***	
		Livestock and manure	5.40		**15**
		Rice cultivation	1.30		
		Other agriculture	1.50		
Waste	3.2	Landfills	1.30		
		Wastewater, other waste	1.50		
Total sectors	**100.00**	**Total uses**	**100.00**	**Total gases**	**100**

* Shares are approximations of real values.
** Nitrous oxide emissions are also due to "Unallocated Fuel Combustion".
*** Methane emissions are also due to "Oil/Gas Extraction, Refining and Processing", "Coal mining" and "Unallocated Fuel Combustion".

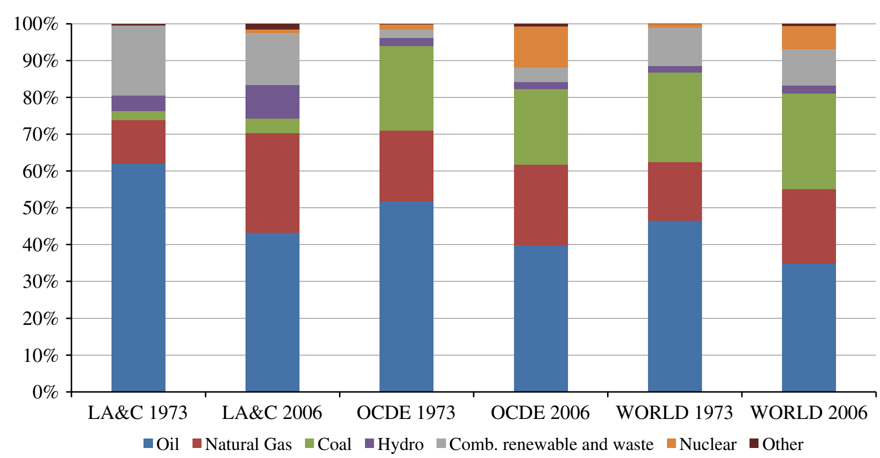

Fig. 1. Composition of Energy Mix by region 1973–2006.
Source: Own elaboration based on BP Statistical Review of World Energy (2009) and OLADE/SIEE (Latin American Energy Organization /Energy-Economic Information System).

biofuels (agrobiofuels) in some countries,[5] in OECD it is mostly represented by liquid biofuels (first generation or agrobiofuels, as well as second generation or advanced biofuels). The use of wood, waste and raw materials is clearly related to income restrictions, and, as discussed by several authors, the lower energy quality of these combustibles is somehow related to low income of poor families. Furthermore, environmental impact of first generation biofuels is quite controversial, as energy and environmental balance is highly dependent on the energy content of the crop and the agricultural system, as well as there is a wide social debate as 100% of these biofuels convert food crops into fuels, this could increase malnutrition worldwide.

Finally, as argue by Stern (2004), changes in economic structures have lead significant reductions in energy intensities in developed countries. This is the previously mentioned composition effect (Grossman and Krueger, 1991). The path development implies a shift

[5] Currently six countries of the region have developed energy policies in order to promote local consumption of biodiesel and bioethanol. To this purpose they have established a fixed quota of share of these biofuels out of total fuels consumptions. Thus Argentina has a quota of 7% for biodiesel and 5% for bioethanol; Bolivia has a 2.5% from 2007 with the objective of 20% in 2015; in Brasil ethanol represents 22% of the fuel consumption, while a share of 5% and 20% has been established for 2013 and 2020, respectively; in Colombia the quota is 10% and 5% for bioethanol and biodiesel; in Paraguay bioethanol has a minimum requirement of 18% and biodiesel 5%; finally, in Peru biodiesel and bioethanol is established to represent 5% and 8%, respectively (Pistonesi et al., 2008).

from energy intensive activities (such as industries) to low energy intensive activities (services). According to Rothman (1998) both panel and cross sectional data proves this shifts in the share of economic sector. The author reproduces the results of Maddison (1989, in Rothman 1998) for the cases of the United States of America and United Kingdom. While in the middle of the 19th century, agricultural sector represented 60% and 40% out of total GDP, respectively, between 1950 and 1960 these share reduced to 10% and 15%, and being lower than 5% in 2000 for both countries. At the same time the contribution of industry to economic activity initially increased and decreased after 1950, reaching a value close to 20% in both countries in 2000. These reductions were offset by an increasing trend in the services sector, which accelerated in both cases at early 20th century, reaching 70% of GDP in 2000. Nonetheless this has not been the case of LA&C. According to data from Earth Trends-WRI (2009), the share of each economic activity has remained stable between 1965 and 2006, even when a slight decreasing trend for agriculture, a growing contribution of services (67% in 2006) and declining one of industry (27.2%), can be observed.

4. Empirical analysis

4.1. Data

In order to analyze the Energy–EKC hypothesis for LA&C countries over the period 1970–2007, a panel on per capita GDP (expressed in 1990 US dollars) and Total Primary Energy Supply (TPES); and per capita GDP Total Primary Energy supply per capita (pcTPES) measured in Ktons of oil equivalent (Ktoe) and Ktoe/inhabitants as energy consumption indicators. The main reason to perform the study with both energy indicators is that we want to evaluate environmental pressure both in absolute and relative terms, taking into account demographic aspects (Zilio, 2011).

The sample consists of 38 annual observations on each of 21 countries,[6] which are available in the Table A1 in the annex. Performing the analysis at aggregate level instead of separate individual estimations allows to more accurate results, as aggregate analysis provides more robustness. In spite of this, we admit that in future extensions of the work it would be good to make a separate study in order to capture the specific characteristics of each country, which could be done only in case of having more extensive series.

Most of the countries of the sample can be classified as underdeveloped or developing countries. Despite this region accounts for 7% of world population, it accounts only for 4% of world GDP. Per capita income of the countries in the sample is within 254 and 10,917 US dollars. According to the World Bank classification[7] this sample consists of three low income economies, ten middle low income economies and eight upper middle income economies. Therefore, this region is characterized by both inequality of income distribution and poverty.

In the first case, according to CEPAL/OLADE the average Gini Index of LA&C is 0.54, while in OECD countries it is 0.31.[8] In the second case, as shown by the CEPAL statistical division in 2007 the average poverty rate was about 34%, with important disparities among countries. The most critical situation can be found in Bolivia (54%), Guatemala (54.8%), Ecuador (42%), Haiti (65%),[9] Honduras (68%), Nicaragua (61%), Paraguay (60.5%) and Peru (44.5%).

Many institutions and authors assert that poverty and energy are strongly linked and the consumption of energy is a useful indicator of the degree of social and economic problems (Pachauri and Spreng, 2003; Shonali and Spreng, 2003; Pereira et al., 2011). Usually the concept of "energy poverty" is applied to people who do not have regular and safe access to electricity, consequently making intensive use of solid fuels (United Nations Development Program, 2000; IEA, 2002; Pereira et al., 2011). This is because energy is an essential ingredient to development. Therefore, increasing energy consumption may be one of the fundamental aspirations of developing regions such as Latin American, Asian and African countries (Pereira et al., 2011). Thus, both access to energy services and access to more efficient sources of energy can be used as indicators of social situation and poverty. In this sense, it is important to highlight the role of some non commercial and inefficient sources of energy in LA&C countries instead of modern sources. In 2006 wood was responsible for 17% of final energy consumption, reaching values significantly higher in Brazil (10.13%), El Salvador (35.98%), Guatemala (45.80%), Guyana (31.84), Haiti (62.55%), Honduras (42.40%), Nicaragua (58.36%), Paraguay (33.38%), Peru (14.01) and Uruguay (22.47%). Furthermore, energy consumption per capita in these countries is lower than in developed countries and world average. The average consumption is nearly 1 toe/hab, even though there is a great disparity among countries,[10] while according to IEA (2008), European-OECD countries consume 3.5 toe/hab, Pacific-OECD countries consume more than 4 toe/hab and North American region consume on average 6 toe/hab. This disparity may be explained both by income disparity and different cultural patterns between regions.

On the other hand, there are some energy characteristics of the region, which may be useful to understand the results of the study. Firstly, while some of these countries have a high share of hydrocarbons in their primary energy mix, for poorest countries the role of biomass in primary energy supply is very important. Furthermore, the share of new Renewable Energy Technologies (RETs) is quite low for most of the countries, being hydro the main renewable source, which plays a crucial role in energy supply for many countries of the region. Secondly, according to information from OLADE (2007), in many countries power generation is concentrated in thermal generation, and in some others hydro generation is very significant.[11] Both issues become relevant in a context of high prices of hydrocarbons, insecurity on its supply and environmental impact of thermal power generation. Finally, only seven of the selected countries have important endowments of hydrocarbon resources. Total AL&C oil reserves reach 126.72 Gbbl (10.3% of world reserves). 87.04 of these

[6] Data are available under request.

[7] World Bank establishes four classifications based on income: high income, upper middle income, middle income and low income. The current basis of the classification is data from 2007. Incomes below $935 fall under low income economies. $936–$3,705 falls under lower middle income economies. $3706–$11,455 of per capita income is classified as upper middle income economies and above $11,455 of per capita GNI qualifies as a high income economy.

[8] According to information provided by OECD Statistical Division, income inequality substantially differs between OECD members. In fact, while some countries exhibit Gini index under 0.30 (Germany, Austria, Belgium, Denmark, Czech Republic, France, Hungary), other countries reach values near to 0.40 (Spain, Italy, USA, among others).

[9] Last information provided on 1987 by Earth Trends-WRI.

[10] Haiti and Peru register a consumption of 0.27 and 0.43 toe/hab, respectively, while energy consumption of others countries of the sample is upper 1 toe/hab. Generally, countries with lower energy consumption are also poorest and present a higher degree of income inequality.

[11] Argentine (hydro 44%, thermal 47%), Brazil (hydro 83%, thermal 13%), Chile (hydro 48%, thermal 52%), Colombia (hydro 76%, thermal 24%), Dominican Republic (hydro 11%, thermal 87%), Ecuador (hydro 48%, thermal 51%), El Salvador (hydro 44%, thermal 35%, others 20%), Guatemala (hydro 41%, thermal 56%), Guyana (thermal 100%), Haiti (hydro 84%, thermal 15%), Honduras (hydro 34%, thermal 65%), Mexico (hydro 10%, thermal 84%, nuclear 4%), Paraguay (hydro 99%), Peru (hydro 71%, thermal 28%), Suriname (hydro 83%, thermal 16%), Trinidad and Tobago (hydro 1%, thermal 98%), Uruguay (hydro 64%, thermal 35%), Venezuela (hydro 73%, thermal 26%).

belong to Venezuela, 18.17 to Brazil,[12] 10.65 to Mexico, 4.46 to Ecuador and 2.59 Gbbl to Argentine. Concerning natural gas, reserves of the region represent 4% of worldwide total. Once again, Venezuela leads with 4708 Gm^3 en 2006, followed by Bolivia (616 Gm^3), Brazil (588.62 Gm^3) Mexico (536.81 Gm^3), Trinidad and Tobago (526.04 Gm^3) and Argentine (446.16 Gm^3). Finally, Brazil has 75% of mineral carbon reserves of LA&C (32.33 Gton) followed by Colombia (6.89 Gton). These data clearly show the minor endowment of this resource for power generation on the region.[13]

Summary statistics for the variables used in this analysis before applying logarithmic transformation proposed by model specification- are presented in Table 2.[14]

4.2. Methodology

During the last years, many authors have emphasized on temporal properties of the series employed on econometric EKC analysis. They assert that lack of attention on these particularities turn into spurious most of the results, thus in order to avoid these problems, and regarding that the EKC is a long term phenomena, many authors have tested the hypothesis using cointegration techniques (Perman and Stern, 1999, 2003; Müller-Fürstenberger et al., 2004; Müller-Fürstenberger and Wagner, 2004; Romero-Ávila, 2008; Song et al., 2008; Galeotti et al., 2009). The theoretic underpinning of this evaluation is that if two variables have a long term relation, then they share a stochastic trend, if not the relation may be spurious. As stated by Galeotti et al. (2009), according to the theory of integrated time series if two variables are integrated of order one, I(1), their linear combination must be integrated of order zero, in that case the relationship is statistically and hence economically meaningful. If not, the inference on the EKC, as any other economic study, produces misleading results. Then, even before assessing the shape or other features of the estimated EKC, the researcher should make sure that the variables, if nonstationary, are cointegrated. It is therefore necessary to run unit root and cointegration tests to guarantee the existence of a well-defined EKC.

Thus, in order to examine the functional relation between per capita GDP and energy consumption (global and per capita) we firstly perform several recent developed tests in order to study the stationarity and cointegration of the series.

The proposed model adjusts to the simplest specification of EKC. This issue does not imply the ignorance of a great number of factors that clearly the energy consumption which should be included in the regression. However, the aim of the simplest model is to capture, if exist, the empirical relation between per capita income and energy consumption. Thus the proposed specifications are the following:

$$\ln TPES_{it} = \beta_0 + \beta_1 \ln pcGDP_{it} + \beta_2 \ln pcGDP_{it}^2$$

and

$$\ln pcTPES_{it} = \beta_0 + \beta_1 \ln pcGDP_{it} + \beta_2 \ln pcGDP_{it}^2$$

where i is the country; t is year (1970–2007); $TPES_{it}$=Total Primary Energy Supply (in KToe) of country i on year t; $pcGDP_{it}$=per capita Gross Domestic Product (1990 US dollars) of country i on year t; $pcTPES_{it}$=per capita Total Primary Energy Supply (in KToe) of country i on year t.

[12] Between 2005 and 2006, Brazil surpassed Mexico reaching the second place on the list due to an increase of 54% into their oil reserves proven.

[13] *Source*: IEA (2008).

[14] The software used for all the econometric analysis has been E-Views 7, except for the Pesaran Test, which was performed using Stata 11.

Table 2
Descriptive statistics[a].

Variable	Obs.	Mean	Std. Dev.	Min	Max
pcGDP [b]	793	2542.868	1953.107	254.78	10,917.76
TPES [c]	798	23,503.77	41,792.36	119.76	23,7031.1
pcTPES[d]	798	1.479429	2.861643	0.1727	24.4770

[a] Data corresponds to 21 LA&C countries during the 1970–2007 period.
[b] Per capita GDP (1990 US dollars). *Source*: OLADE-SIEE.
[c] Total primary energy supply, measured in Ktoe. *Source*: OLADE-SIEE.
[d] Per capita total primary energy supply, measured in Ktoe per inhabitants.

5. Empirical results

5.1. Unit root results

As previously mentioned, we firstly performed several tests in order to study the stationarity and cointegration properties of the series. In this section we take into account two types of panel unit root tests. First, we consider three of the so called first generation panel unit root tests designed for cross-sectionally independent panels, which are widely used in the EKC literature up to now. In case of verifying such independence, traditional asymptotic theory for unit root and cointegration will be applicable. Technically, all first generation tests share the null hypothesis of stationarity but diverge on the alternative one, which can be homogeneous or heterogeneous.[15]

Afterwards we perform a second generation panel unit root tests that allow handling cross-sectional correlation, a more realistic assumption for economic series in general, and for EKC in particular, due to the fact that energy pattern and GDP are probably highly related in countries belonging to the same region.

In order to enhance the robustness of the stationarity analysis we applied three first generation tests, Levin, Lin and Chu (LLC), Im, Pesaran and Shin (IPS) and Fisher-Philips Perron (F-PP); and one second generation test, Pesaran, which recognizes the existence of cross sectional dependence. Table 3 displays the results of these panel unit root tests. None of the series are stationary in levels, but they are in fist difference, confirming that all of them are I(1) series.

5.2. Cointegration results

Once verified that series involved in EEKC estimation are all I(1), we perform panel cointegration test in order to determine the existence of a long term relationship between them.

The considered first generation panel cointegration tests are designed for cross sectionally independent panels and are very similar to the first generation panel unit root tests discussed above, testing the null hypothesis of no cointegration. In this paper we report the results based on the tests of Pedroni (2004), who develops four pooled tests against the homogenous alternative (weighted and no weighted) and three group-mean tests against the heterogeneous alternative. Three of the four pooled tests are based on a first-order autoregression and correction factors in the spirit of Phillips and Ouliaris (1990). These are a variance-ratio statistic, a test statistic based on the estimated first-order correlation coefficient, and a test based on the t-value of the correlation coefficient. The fourth test is based on an ADF type test statistic, in which the correction for serial correlation is achieved by augmenting the test equation by lagged differenced

[15] For a detailed description of panel unit root and cointegration tests applied see Hlouskova and Wagner (2006) and Wagner (2008).

Table 3
Panel unit root tests.

	First generation						**Second generation**	
	***H$_a$*: $\rho_i = \rho < 1$**		***H$_a$*: $\rho_i < 1$**					
	LLC		**IPS**		**Fisher (PP)**		**Pesaran**	
	Individual intercept	Individual intercept and trend	Individual intercept	Individual intercept and trend	Individual intercept	Individual intercept and trend	Individual intercept	Individual intercept and trend
TPES	0.489	0.214	2.844	0.997	30.364	49.597	−1.393	0.331
d(TPES)	**−12.24****	**−11.45****	**−14.56****	**−13.00***	**471.01****	**1375.4****	**−11.77****	**−10.183****
pcTPES	−1.80445	−0.6946	−0.68395	0.4848	58.4187	40.4217	0.497	0.523
d(pcTPES)	**−12.91****	**−12.22****	**−14.33****	**−12.88****	**485.81****	**821.59****	**−12.02****	**−9.79****
pcGDP	2.8522	1.7221	2.8817	2.8812	20.0094	14.1311	1.689	1.135
d(pcGDP)	**−10.65****	**−10.36****	**−10.22****	**−8.50****	**342.51****	**283.97****	**−8.18****	**−6.56****
pcGDP^2	5.5560	3.4217	4.8025	4.2560	15.5554	10.5203	2.793	2.601
d(pcGDP^2)	**−9.15****	**−9.99****	**−9.29****	**−8.09****	**320.04****	**273.67****	**−8.19****	**−6.761**

* Indicates rejection of the null hypothesis at the 5% level.
** Rejection at the 1% level.

Table 4
Pedroni cointegration test.

	Individual intercept	**Individual intercept and individual trend**	**Nor intercept or trend**
TPES, per capita GDP and per capita GDP squared			
Alternative hypothesis: common AR coefs. (within-dimension)			
Panel v-statistic	**5.534196****	1.635137	−2.956867
Panel rho-Statistic	0.106201	2.431781	1.769493
Panel PP-statistic	1.554750	4.088142	1.889993
Panel ADF-statistic	0.733893	2.608974	2.558505
Alternative hypothesis: individual AR coefs. (between-dimension)			
Group rho-statistic	1.843048	3.209348	Statistic
Group PP-statistic	2.137030	3.567268	2.994328
Group ADF-statistic	0.992546	2.219605	2.420499
pcTPES, per capita GDP and per capita GDP squared			
Alternative hypothesis: individual AR coefs. (between-dimension)			
Group rho-statistic	1.898481	3.267525	2.491361
Group PP-statistic	2.213799	3.846087	1.648238
Group ADF-statistic	1.132156	2.507504	2.090781

** Indicates rejection of the null hypothesis at the 1% level.

residuals of the cointegrating regression. Thus, this test is a panel cointegration analog of the LLC panel unit root test presented on the previous section. Moreover, Pedroni proposes the group-mean statistics, analogs of all but the variance ratio test statistic, providing a total of eleven contrast statistics.

The Pedroni cointegration tests results, partially reported in Table 4, indicate no existence of long run relationship, neither for TPES and pcGPD, nor for pcTPES and pcGDP. For both cases, only one of the eleven statistics (panel-v) is significant at 5% level. For the case of TPES this is under the individual intercept specification, and for pcTPES under the individual intercept and trend specification. Thus, we do not have enough evidence to verify the existence of a long term relationship between GDP per capita and TPES (in absolute and relative terms) for the sample during the 1970–2007 period according to the EKC hypothesis.

6. Concluding remarks

This paper presents the empirical findings of cointegration between energy consumption, in absolute and relative terms, and per capita GDP in the case of a panel composed by 21 LA&C countries, in order to analyze the environmental impact of energy consumption in the frame of energy EKC hypothesis.

For this purpose recent panel unit root and panel cointegration tests have been performed to the sample. Our findings show no evidence supporting the existence of a stable long term relation between the series, in none of the cases. Then, for this sample, the Energy EKC should be rejected. However, we do admit that data availability may weaken the robustness of our results, as the sample could not be long enough to carry out a long run econometric analysis.

Nevertheless, beyond these problems, there are several possible explanations to the results. All of them maintain a straight linkage with the characteristics of the countries in the sample, such as development degree, income distribution and other aspects, no directly related to GDP that could also affect the energy consumption. Unfortunately, there is not enough data for these variables for LA&C, which does not allow performing an econometric analysis and then the significance of these factors cannot be tested at this moment.

However, in the frame of this study, the composition of the energy mix is of particular interest to discuss the relation between per capita GDP and energy consumption. As mentioned in Section 3 many countries in the sample have a primary energy mix based on fossil resources. Some exceptions are countries in which biomass have a higher share, directly related with social aspects, and others with a significant share of hydro energy.

At the same time, while the recent worldwide trend has been to introduce new sources of renewable energy, excluding big hydro energy plants and non modern biomass; it has not been the case of most of LA&C countries. Firstly, the social and economic situation of countries in the sample weakens the demand of "green technologies", making it very low compared with the registered on developed countries, in which energy demand is able to absorb electricity supply from renewable sources, clearly more costly than generated from conventional technologies. Secondly, evidence shows that just some countries had success in diversification of their energy, and particularly electricity mixes. In such cases the use of energy policy, including economic incentive mechanisms, has been crucial (Haas et al., 2004; Laird and Stefes, 2009). Conversely, for some countries in the sample energy policy has been mainly focused on supplying primary requirements with more efficient sources. Nevertheless, countries in the sample with a higher level of income and energy coverage have recently experienced the trend to design the institutional framework required to develop this kind of energy sources. Brazil, Argentine, Colombia and Chile are the most important examples.

In the case of developing countries achieving security of supply, diversifying energy mixes and promoting rational and efficient consumption, through the use of energy policy, seem to be especially important, not only to reduce environmental impact of energy consumption, but also to reduce social vulnerability of many sectors of the society.

Regarding the results of this paper, and as stated by many authors in this field (Hettige et al., 2000; Halkos and Tsionas, 2001; Halkos, 2006; Lise and Van Montfort, 2007; Gales et al., 2007; Nguyen-Van, 2010, among others) the argument of Beckerman (1992) loses relevance. According to it, the best way to improve environmental conditions would be 'wait and grow'. In contrast, under the empirical findings of this case, designing a global energy policy, for each country or region attending to their different requirements, seems to be crucial as the clear relation between energy consumption and GDP is not verified, and then we cannot study its functional form and direction of the causal relation. Furthermore, in the case of the countries of the sample population growth plays a key role on energy consumption, and therefore on the environmental pressure. Historically, the level of human population has been closely related to the level of energy consumption and population is one of the main determinants of environmental impact (Erlich and Holdren, 1971). Population growth and its consequent impact may be even more important in underdeveloped and developing countries. Thus population growth may exert a higher environmental pressure on these countries both for its magnitude as well as for their economic dependence on natural resources.

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Appendix A. Data and sources

Our analysis is based on panel data for 21 countries over the period 1970–2007 listed below in Table A1.

Table A1
List of countries included in the computations.

Argentina	Ecuador	Nicaragua
Bolivia	El Salvador	Paraguay
Brazil	Guatemala	Peru
Chile	Guyana	Suriname
Colombia	Haiti	Trinidad and Tobago
Costa Rica	Honduras	Uruguay
Dominican Republic	Mexico	Venezuela

Appendix A. Supplementary information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.enpol.2011.09.049.

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