THE RELATIONSHIPS BETWEEN TOTAL, ELECTRICITY AND BIOFUELS RESIDENTIAL ENERGY CONSUMPTION AND INCOME IN LATIN AMERICA AND THE CARIBBEAN COUNTRIES

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Abstract:

Controlling residential energy consumption in Latino America and the Caribbean countries is crucial to reduce CO2 emissions, as it has an important energy-saving potential, and its environmental controls are difficult to displace offshore. The aim of this study is to analyze the relationships between residential energy consumption and income for 22 Latin America and the Caribbean countries in the period 1990-2013. For this purpose, residential energy environmental Kuznets curves (EKC) are estimated by taking into account the heterogeneity among the countries by including two control variables: one representing the possible effect of urbanization on residential energy use and the second representing the possible effect of petrol production.

The EKC are estimated for total residential energy consumption, for residential electricity consumption and for biofuels and waste energy consumption. The elasticities of total, electricity and biofuels residential energy consumption with respect to income are calculated for each year and country, analyzing the different behavior between countries. Obtained results show that the EKC hypothesis is confirmed for the residential sector when the biofuels energy consumption is considered.

Moreover, the results also show that the turning point has been reached in some countries. Nevertheless, the EKC is not confirmed when electricity or total residential energy consumption is considered. Thus, for total residential energy consumption, the elasticity is always positive, growing also as the income does. For electricity energy consumption, the elasticity is also always positive, since although the elasticity decreases until a threshold, from an per capita income value it begins to grow.

Keywords: Latin America and the Caribbean Countries, Environmental Kuznets Curve, Residential energy consumption, Energy consumption-income elasticities

JEL codes: C23, O52, Q43, Q52

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1. Introduction

Energy consumption is the main cause of CO_2 emissions, so controlling its growth is going to be crucial (Soytas et al. (2007). However, while emissions growth could be controlled by reducing energy consumption, this reduction could also have negative effects on economic growth (Lotfalipour et al., 2010). The relationship between energy consumption and economic growth has been widely studied in recent literature, receiving a new important attention from the environmental perspective (Pablo-Romero and Sánchez-Braza, 2017a). This dynamic relationship between economic growth, energy consumption and environmental pressure has been analyzed for different regions and countries (Chang and Carballo, 2011; Wang et al., 2011; Arouri et al., 2012; Hamit-Haggar, 2012; Omri, 2013; Apergis and Payne, 2014; Cowan et al., 2014; Kasman and Duman, 2015; Pablo-Romero and De Jesús, 2016). Thus, an in-depth knowledge of this relationship is considered to be extremely important for the development of effective energy and environmental policies to promote sustainable development.

Moreover, energy use in residential buildings is one of the largest sources of direct and indirect CO_2 emissions (U.S. Energy Information Administration, 2013; Estiri, 2015). So, energy consumption in the residential sector is an area with great potential for implementing energy saving policies, which could be achieved not only through technical measures, but also by improving consumer behavior (Ouyang and Hokao, 2009). Likewise, the applied energy policies may be more globally-effective in this sector than in others, thus, the analysis of the evolution of residential energy use becomes interesting (Pablo-Romero and Sánchez-Braza, 2017b). Anyway, it is necessary to thoroughly understand the relationship between economic growth and energy consumption in general, and in the residential sector in particular, to be able to develop environmental and energy efficiency policies, as increasing energy demand is at the centre of the environmental problem (Canadell et al., 2007).

Otherwise, in the case of Latino America and the Caribbean countries controlling becomes crucial to reduce CO_2 emissions, as it has an important energy-saving potential, and its environmental controls are difficult to displace offshore.

The aim of this study is to analyze the relationships between residential energy consumption and income for 22 Latin America and the Caribbean countries in the period 1990-2013. For this purpose, residential energy environmental Kuznets curves (EKC) are estimated by taking into account the heterogeneity among the countries by including two control variables: one representing the possible effect of urbanization on residential energy use and the second representing the possible effect of petrol production. The EKC are estimated for total residential energy consumption, for residential electricity consumption and for biofuels and waste (biomass) energy consumption. From the estimate results, the elasticities of total, electricity and biofuels residential energy consumption with respect to income are calculated for each year and country according to Pablo-Romero and Sánchez-Braza (2015), analyzing the different behavior between countries.

Thus, this paper is organized as follows: Section 2 analyzes the methodology used; Section 3 describes the database and the evolution of residential energy consumption and economic growth. Results and discussions are contained in Section 4. Finally, Section 5 concludes.

2. Methodology

The general specification model for testing the EKC is expressed as follows:

$$E_{it} = A_{it} + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 Y_{it}^3 + e_{it} \quad \textbf{(1)}$$

Where:

E is a measure of environmental pressure, being in this study the energy final consumption per capita by the residential sector in natural logarithms, and considering total residential energy (*RECpc* variable), electricity (*RElCpc* variable) and (*RBCpc* variable) biomass consumption; *Y* is the independent variable of income per capita expressed in logarithms, in this case GDP (*GDPpc* variable); *A* represents the sum of time and country effects; β_1, β_2 and β_3 are the parameters of the function to be estimated; *i* and *t* denote countries and years, respectively, being *i* equal to 1, 2..., 22 countries of the sample, and *t* from 1990 to 2013; finally, *e* is a random error term.

β coefficients values informs about the form of relationship between the variables of residential energy consumption per capita and *GDPpc*.

The Equation [1] may be estimated including and excluding the cubic term of the variable *Y*, since both specifications are estimated in previous studies. However, according to Luzzati and Orsini (2009), estimations with a cubic term give a greater flexibility to the model. So, this is the option estimated in this study.

In order to take into account the heterogeneity of the sample, two control variables have been included in the model (Piaggio and Padilla, 2012). On one side, a control variable representing the percentage of population living in urban areas has been included (*Urb variable*). This control variable measures the possible effect of represents the possible effect of urbanization in the residential energy consumption. In this sense, previous studies consider state that urbanization may affect the energy use in the residential sector, with it being less energy-intensive in rural areas (Wiedenhofer et al., 2013; Heinonen and Junnila, 2014). Due to the importance of urbanization in economic development, the relationship between urbanization and energy consumption or energy-related CO_2 emissions has been extensively studied, in terms of cross-countries, time-series or panel scopes (Poumanyvong and Kaneko, 2010; Al-mulali et al. 2012, 2013; Zhang et al., 2015; Shahbaz et al., 2016; Wang et al., 2016). However, most of these studies investigate energy consumption as a gross term, especially ignore the difference between residential sector and other production sectors.

On the other hand, a second control variable has been included in order to consider the possible effect of petrol production on residential energy consumption. So, oil production (*Oil* variable) has been considered expressed in percentage of total production. Therefore, the equation to be estimated may be reformulated as:

$$E_{it} = A_{it} + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 Y_{it}^3 + \phi_1 Urb_{it} + \phi_2 Oil_{it} + e_{it} \quad \textbf{(2)}$$

Several econometric problems have been observed in previous studies when estimating the EKCs. At first, some authors such as Narayan and Narayan (2016) and Narayan et al. (2016) have perceived multicollinearity problems among the explanatory variables. In this paper, the severity of multicollinearity among the explanatory variables was first quantified by using the values of the variance inflation factors (VIFs) (Sánchez-Braza and Pablo-Romero, 2014). Once this problem was shown, the data were converted to deviations from the geometric mean of the sample to mitigate it. This transformation avoids the multicollinearity among the variables, which is tested again by using the VIF values. These VIF values are reported in Table 1, including values obtained for the variables, both with and without being converted to deviations from the geometric mean of the sample. As observed, the VIF values do not exceed the value of 5 for any converted explanatory variable, ruling out possible problems of multicollinearity when considering the variables expressed in terms of deviations with respect to its geometric mean.

Table 1
Variance inflation factors.

Variables	VIF (variables)	VIF (deviations from the geometric mean)
Y	1399.68	4.07
Y^2	6410.57	2.63
Y^3	1905.09	4.74
Urb	1.61	1.61
Oil	1.15	1.15
Mean VIF	1120.22	2.89

Source: Own elaboration.

Using a topline over variables to indicate these deviations, it is possible to rewrite **(2)**, as follows:

$$\overline{E}_{it} = \overline{A}_{it} + \beta_1 \overline{Y}_{it} + \beta_2 \overline{Y}^2_{it} + \beta_3 \overline{Y}^3_{it} + \phi_1 \overline{Urb}_{it} + \phi_2 \overline{Oil}_{it} + e_{it} \quad \textbf{(3)}$$

Additionally, in order to avoid spurious estimates (Stern, 2014), the stochastic nature and properties of the variables were examined: firstly, cross-section dependence in the data was tested by using the Pesaran (2004) CD test; secondly, the Pesaran (2007) second generation panel unit roots tests (CIPS tests) were used to investigate the presence of unit roots; finally, the error correction based on panel cointegration tests proposed by Westerlund (2007) was implemented to test the existence of a structural long-run relationship among the variables. Taking into account the previous tests results, the data were also transformed into first differences, therefore being similar to expressing the EKC in terms of long-run growth rates (Anjum et at., 2014). Using Δ to indicate first differences, it is possible to rewrite **(3)** as follows (where $\overline{\Delta A_{it}} = \delta_t$):

$$\Delta\overline{E}_{it} = \delta_t + \beta_1 \Delta\overline{Y}_{it} + \beta_2 \Delta\overline{Y}^2_{it} + \beta_3 \Delta\overline{Y}^3_{it} + \phi\Delta\overline{C}_{it} + \phi\Delta\overline{C}_{it} + e_{it} \quad \textbf{(4)}$$

Once the Equation **(4)** has been estimated, the β coefficients obtained may inform about the relationships between the E and Y variables. If all β coefficients are positive, then an increasing relationship exists between E (residential energy consumption) and Y (*GDPpc*). However, the EKC hypothesis is verified and presents the classic inverted U shape if $\beta_1>0$, $\beta_2<0$ and $\beta_3\leq0$. Likewise, if $\beta_1>0$, $\beta_2>0$ and $\beta_3<0$, the curve may present the U shape from a certain Y value, which depends on the β coefficients values. Alternatively, if $\beta_1>0$, $\beta_2<0$ y $\beta_3>0$, then the curve presents a N shape (Dinda, 2004). In the case that the EKC exists, a threshold or a turning point may be calculated, making the elasticity of E with respect to Y equal to zero.

Then, from the estimate results, the elasticities of total, electricity and biofuels residential energy consumption with respect to income are calculated for each year and country according to Pablo-Romero and Sánchez-Braza (2015), analyzing the different behavior between countries. This elasticity may be calculated for each year and country as follows:

$$elas_{it} = \beta_1 + 2\beta_2 \overline{Y}_{it} + 3\beta_3 \overline{Y}_{it}^2 \quad \textbf{(5)}$$

These elasticities measure the residential energy (total, electricity or biomass) consumption sensitivity with respect to a change in the *GDPpc*, for each year and country. Thus, it is a measure of the responsiveness of *E* to an increase in *Y*. Therefore, these elasticities allow the possibility of analyzing different behavior between countries.

3. Data.

3.1. Data sources.

This study uses a panel data of 22 countries over the period 1990-2013. The countries included in the analysis are the followings: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad, Uruguay and Venezuela.

Residential energy consumption data proceed from the International Energy Agency (IEA, 2017) which offers energy data for its member countries as well as for wide range of non-member countries. Energy final consumption per capita by the residential sector is analyzed, considering total residential energy (*RECpc* variable), electricity (*RElCpc* variable) and (*RBCpc* variable) biomass consumption. Data are expressed in natural logarithm of kilograms of oil equivalent consumption by the residential sector per inhabitants.

The rest of the data (GDP, total population, urban population and oil production) come from the World Bank Development Indicators (World Bank, 2017). Total population is used to convert energy consumption and income expressed in absolute terms in per capita terms. *Y* variable is expressed in natural logarithm of GDP in constant 2005 U.S. dollars per inhabitants. *Urban population* variable (*Urb* variable) is expressed in percentage of total population. Finally, *Oil production* (*Oil* variable) variable is expressed in percentage of total production.

3.2. Descriptive analysis.

Table 2 presents the main descriptive statistics of the variables used to estimate the models. The *between statistics* refer to the average data values of each individual country, while the *within statistics* refer to intra groups values over time for each country and to the variation from each individual country’s average. Table 2 shows that the standard deviation of the data across countries is higher than across time for all variables during the considered period.

Table 2

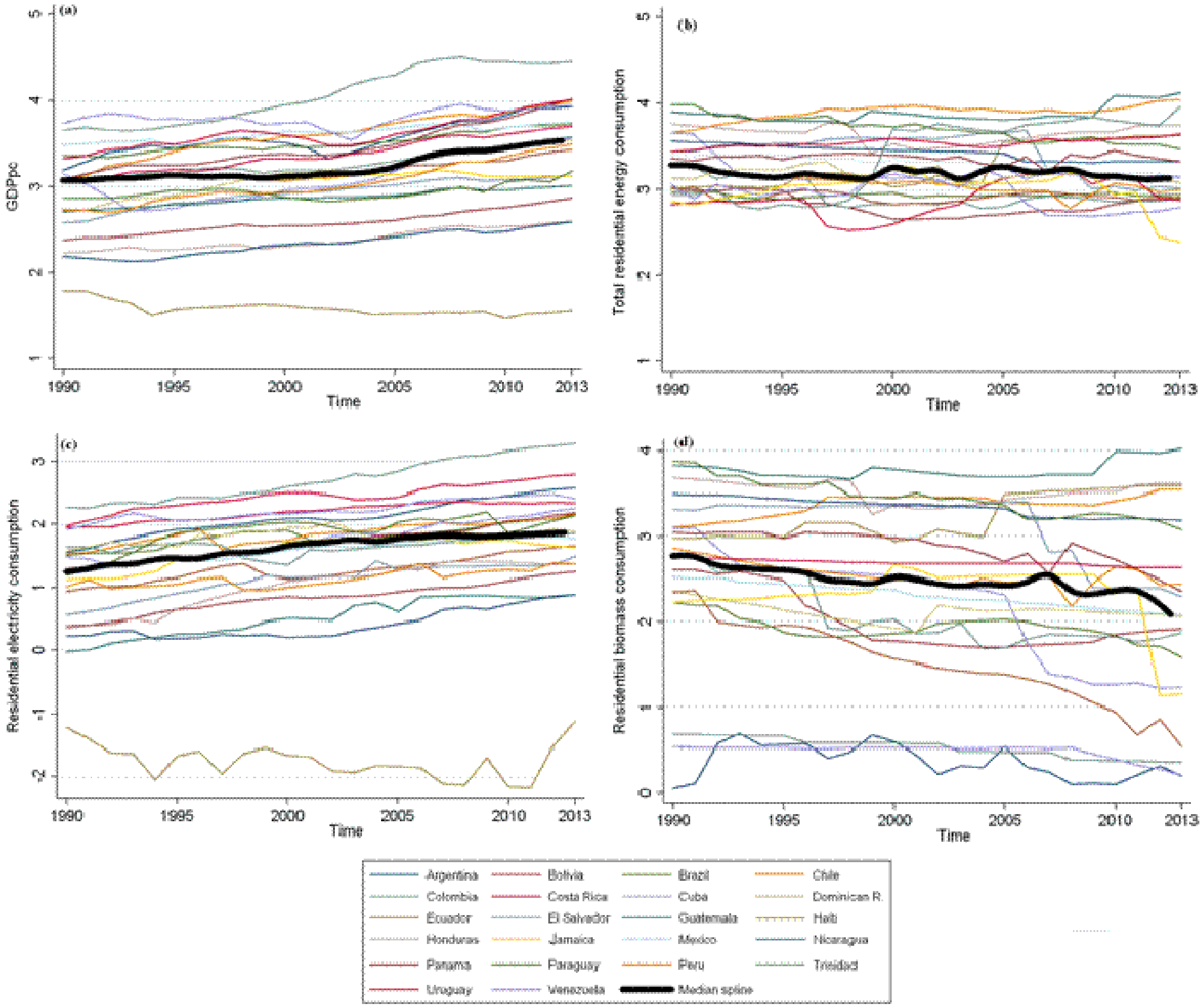
Descriptive statistics (1990-2013).

Variable		Mean	Std. Dev.	Min.	Max.	Observations
Residential energy consumption pc (in logs) (*RECpc*)	overall	3.119	0.801	-0.820	4.120	N = 528
	between		0.796	-0.149	3.895	n = 22
	within		0.186	2.448	3.717	T = 24
Residential electricity consumption pc (in logs) (*RElCpc*)	overall	1.449	0.935	-2.180	3.280	N = 528
	between		0.926	-1.749	2.717	n = 22
	within		0.235	0.761	2.078	T = 24
Residential biomass consumption pc (in logs) (*RBCpc*)	overall	2.353	1.009	0.050	4.030	N = 528
	between		0.988	0.364	3.785	n = 22
	within		0.290	1.159	3.259	T = 24
GDPpc (*Y*) (in logs)	overall	3.143	0.575	1.470	4.500	N = 528
	between		0.559	1.585	4.067	n = 22
	within		0.179	2.615	3.696	T = 24
% of urban population (*Urb*)	overall	63.928	19.113	8.534	94.983	N = 528
	between		19.148	9.614	92.262	n = 22
	within		3.828	52.050	79.708	T = 24
% of oil production (*Oil*) (in logs)	overall	5.077	4.852	0.000	12.190	N = 528
	between		4.956	0.000	12.025	n = 22
	within		0.234	3.775	5.785	T = 24

Source: Own elaboration.

Figure 1

Descriptive statistics (1990-2013).Evolution of *GDPpc*, *RECpc*, *RElCpc* and *RBCpc* (1990-2013).



Source: Own elaboration from IEA (2017) and World Bank (2017).

Figure 1 shows the evolution of GDPpc in logs (Graph a), and the evolution of total residential energy (*RECpc*, Graph b), electricity (*RElCpc*, Graph c) and biomass consumption (*RBCpc*, Graph d) in logs and in per capita terms for the 22 analyzed countries over the period 1990-2013. The data for each country are represented

individually by a color line. Additionally, the median spline of all countries for each year is represented by black line.

The evolution of *GDPpc* (Graph a) shows a clear positive trend over the period analyzed for all the countries, with the exception of Haiti, which has suffered diverse natural disasters over these years. Remarkable differences between countries GDPpc values may be observed. The countries with the highest GDPpc levels are Trinidad, Uruguay, Venezuela, Chile, Mexico and Argentina. On the other hand, Haiti, Nicaragua, Honduras and Bolivia register a below average level GDPpc.

The evolution of *RECpc* (Graph b) shows a stable trend during the analyzed period, with small ups and downs in some countries. Otherwise, the evolution of residential electricity consumption (*RElCpc*, Graph c) manifests a clear growing trend for all the considered countries, anew with the exception of Haiti. Finally, in relation to the evolution of residential consumption (*RBCpc*, Graph d), while it seems to maintain in general terms a slight decreasing trend, this evolution evinces important ups and downs in the case of several countries as Costa Rica, Argentina and Honduras, although these countries show similar values between the initial and final years of the considered period. In the case of other countries, although at the beginning of the period the trend was relatively constant, they show a remarkable increasing or decreasing trend at the end of the considered period, as Guatemala and Chile in the first case, or Paraguay, Jamaica, Bolivia and Ecuador in the second one.

4. Results and discussion.

4.1. Estimate results.

Tables 3, 4 and 5 show the estimate results of the Equation **(4)** for the 22 countries during the period 1990-2013. The estimates are obtained using the feasible generalized least squares (FGLS) method in the presence of autocorrelation, heteroscedasticity and contemporaneous correlation, according to the results of the Wooldridge (2002) test for autocorrelation, the Wald test for homoscedasticity proposed in Greene (2000), and the

Pesaran (2004) test for contemporaneous correlation. All estimates included time dummies, and have been estimated in first differences in order to avoid spurious estimates, in accordance with the previous econometric analysis of the data properties.

Table 3

Estimate results of Equation **(4)** for residential energy consumption.

	(a)	(b)	(c)	(d)
Y	0.245*** (0.043)	0.200*** (0.049)	0.149*** (0.043)	0.156*** (0.045)
Y^2	0.055* (0.030)	0.085** (0.034)	0.054** (0.026)	0.057** (0.029)
Y^3	0.048** (0.024)	0.053* (0.030)	0.036* (0.022)	0.042** (0.023)
Urb		0.011 (0.007)		0.007 (0.007)
Oil			-0.127*** 0.014	-0.123*** (0.014)

*Note: Standard errors are shown in parenthesis, *** denotes significance at the 1% level, ** at the 5% level and * at the 10% level.*

Table 3 shows the estimates when total residential energy consumption is considered. The results indicate that the β_1 coefficient is significant and positive in all specifications, which means that the elasticity of the residential energy consumption per capita with respect to GDPpc is positive in the central point of the sample. All estimates evince that both β_2 and β_3 coefficients are positive and significant in all specifications. Then, the results show that the EKC hypothesis is not supported for residential energy consumption.

It also should be noted that the estimated coefficient for *Urb* variable is not significant, while the estimated coefficient for *Oil* variable is significant and negative.

Table 4

Estimate results of Equation **(4)** for residential electricity consumption.

	(a)	(b)	(c)	(d)
Y	0.331*** (0.039)	0.343*** (0.034)	0.321*** (0.040)	0.331*** (0.040)
Y^2	-0.250*** (0.022)	-0.246*** (0.021)	-0.249*** (0.022)	-0.258*** (0.022)
Y^3	0.258*** (0.025)	0.254*** (0.023)	0.258*** (0.025)	0.255*** (0.025)
Urb		-0.007** (0.003)		-0.009*** (0.004)
Oil			-0.011 (0.009)	-0.012 (0.009)

*Note: Standard errors are shown in parenthesis, *** denotes significance at the 1% level, ** at the 5% level and * at the 10% level.*

Table 4 shows the estimates when residential electricity consumption is considered. The results manifest that the β_1 coefficient is significant and positive in all specifications, which means that the elasticity of the residential electricity consumption per capita with respect to GDPpc is positive in the central point of the sample. All estimates show that this value is around 0.33. In addition, the results show that β_2 coefficient is negative and β_3 is positive, with values around -0.25 and 0.25 respectively, and being both significant in all specifications. In this way, as if $\beta_1>0$, $\beta_2<0$ and $\beta_3>0$, the EKC hypothesis may be supported for the case of the residential electricity use, and the curve presents a N shape.

In this case, the estimated coefficient for *Oil* variable is not significant, while the estimated coefficient for *Urb* variable is now significant and negative.

Table 5

Estimate results of Equation **(4)** for residential biomass consumption.

	(a)	(b)	(c)	(d)	(e)
Y	0.233*** (0.032)	0.223*** (0.029)	0.195*** (0.034)	0.197*** (0.029)	0.189*** (0.023)
Y^2	-0.082*** (0.018)	-0.052*** (0.015)	-0.088*** (0.015)	-0.050*** (0.015)	-0.062*** (0.015)
Y^3	-0.046*** (0.016)	-0.011 (0.016)	-0.043*** (0.017)	-0.012 (0.016)	
Urb		0.035*** (0.008)		0.033*** (0.008)	0.038*** (0.007)
Oil			-0.029*** (0.006)	-0.025*** (0.007)	-0.023*** (0.006)

*Note: Standard errors are shown in parenthesis, *** denotes significance at the 1% level, ** at the 5% level and * at the 10% level.*

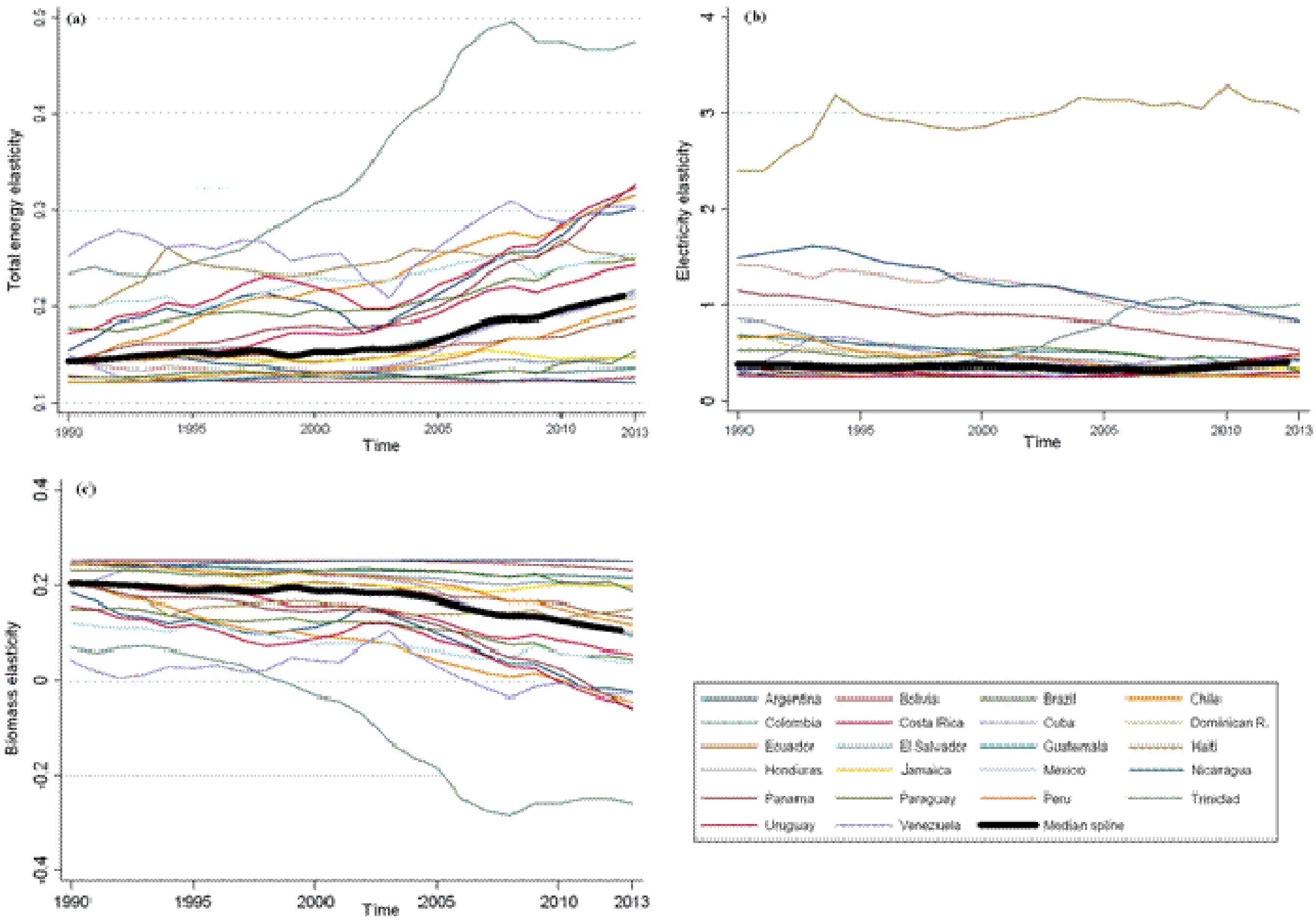
Finally, Table 5 shows the estimates when residential biomass consumption is considered. The results present that the β_1 coefficient is significant and positive in all specifications, which means that the elasticity of the residential biomass consumption per capita with respect to GDPpc is positive in the central point of the sample. The results show that β_2 coefficient is negative and significant in all specifications. However, β_3 coefficient is negative but it is only significant when control *Urb* variable is not considered. Moreover, coefficients for *Urb* and *Oil* variables are both significant, being positive and negative, respectively. In this sense, an additional column (e) has been added in Table 5, including both control variables and excluding the cubic term, being now significant all the considered variables. According to Dinda (2004), the EKC hypothesis is verified and presents the classic inverted U shape as if β_1>0, β_2<0 and if it is applicable $\beta_3 \leq 0$.

4.2. Evolution of residential energy consumption elasticities by countries.

From the β estimated values, the residential energy consumption per capita elasticities with respect to GDPpc have been calculated for each country and year for the period 1990-2013, for the cubic function according to Equation **(5)**. Figure 2 shows the evolution of calculated residential energy consumption per capita elasticities with respect to GDPpc by countries, considering total residential energy (Graph a), electricity (Graph b) and biomass consumption (Graph c) over the period 1990-2013. The data for each country are represented individually by a color line. Additionally, the median spline of all countries for each year is represented by black line.

Figure 2

Elasticity of residential energy consumption (total, electricity and biomass) per capita with respect to GDPpc for the 22 considered countries (1990-2013).



Source: Own elaboration.

First, Graph (a) in Figure 2 shows the evolution of these calculated elasticity values by countries, when total residential energy consumption is considered. The results obtained from estimates in Column (c) in Table 3 were used; therefore the final equation used is the following:

$$ela\ (total)_{it} = 0.149 + 2 * 0.054\Delta \overline{Y}_{it} + 3 * 0.036\Delta \overline{Y}_{it}^{2} \quad \textbf{(6)}$$

The estimated elasticity values are not constant over period analyzed. The black line represents the trend of the elasticity median spline that shows a stable trend during the first tranct of the period considered but an important increasing trend from 2004. Anyway, notable differences among the countries *RECpc* elasticities values are registered, although the great majority of countries show a clear increasing trend in the last years of the period. All estimated elasticity values are positive and are in the range of values between 0.1 and 0.3, with de exception of Trinidad that holds a significant growth, going from the value 0.2 registered in 1990 to almost reaching the value of 0.5 at the end of the period. Among the countries with the highest elasticity values, Panama, Uruguay, Chile, Venezuela and Argentina finalized the period reaching values above 0.3. On the other hand, Paraguay, Jamaica, El Salvador, Guatemala, Bolivia and Nicaragua represent a below average level GDPpc, showing an stable evolution along the considered period around 0.12 value.

Secondly, Graph (b) in Figure 2 shows the evolution elasticity values by countries, when residential electricity consumption is considered. The results obtained from estimates in Column (b) in Table 4 were used; therefore the final equation used is the following:

$$ela\ (elect)_{it} = 0.343 - 2 * 0.246\Delta \overline{Y}_{it} + 3 * 0.254\Delta \overline{Y}_{it}^{2} \quad \textbf{(7)}$$

Noticeable differences between countries elasticity values may be observed. The black line representing the median shows a stable trend with similar values at the initial and final years of the considered period. All values obtained are positive, and in the great majority of cases they are in the range of variation between 0.3 and 0.7. Anyway, some groups of countries with different evolution of their elasticity may be highlighted.

Haiti presents again an exceptional elasticity values with constant with an increasing trend. Nicaragua, Honduras y Bolivia register at the beginning of the period values above the unit, but after a marked downward trend finalized the period with values clearly lower than unity. Conversely, Trinidad is distinguished by a significant upward trend, especially in recent years, starting with an around 0.3 value and finalizing the period with values close to the unity. El Salvador, Dominican Republic, Peru, Guatemala y Peru show values above the average, but with a marked downward trend throughout the whole period. Finally, other countries as Brazil, Mexico, Costa Rica, Colombia and Ecuador have values slightly below the average, showing a constant trend evolution along time.

Thirdly, Graph (c) in Figure 2 shows the evolution elasticity values by countries, when residential biomass consumption is considered. The results obtained from estimates in Column (c) in Table 5 were used; therefore the final equation used is the following:

$$ela\ (biom)_{it} = 0.195 - 2 * 0.088 \Delta \overline{Y}_{it} + 3 * 0.043 \Delta \overline{Y}_{it}^{2} \qquad \textbf{(8)}$$

In general terms, a moderate decreasing trend is registered at the beginning of the considered period that becomes in an important decreasing trend from 2004-2005.

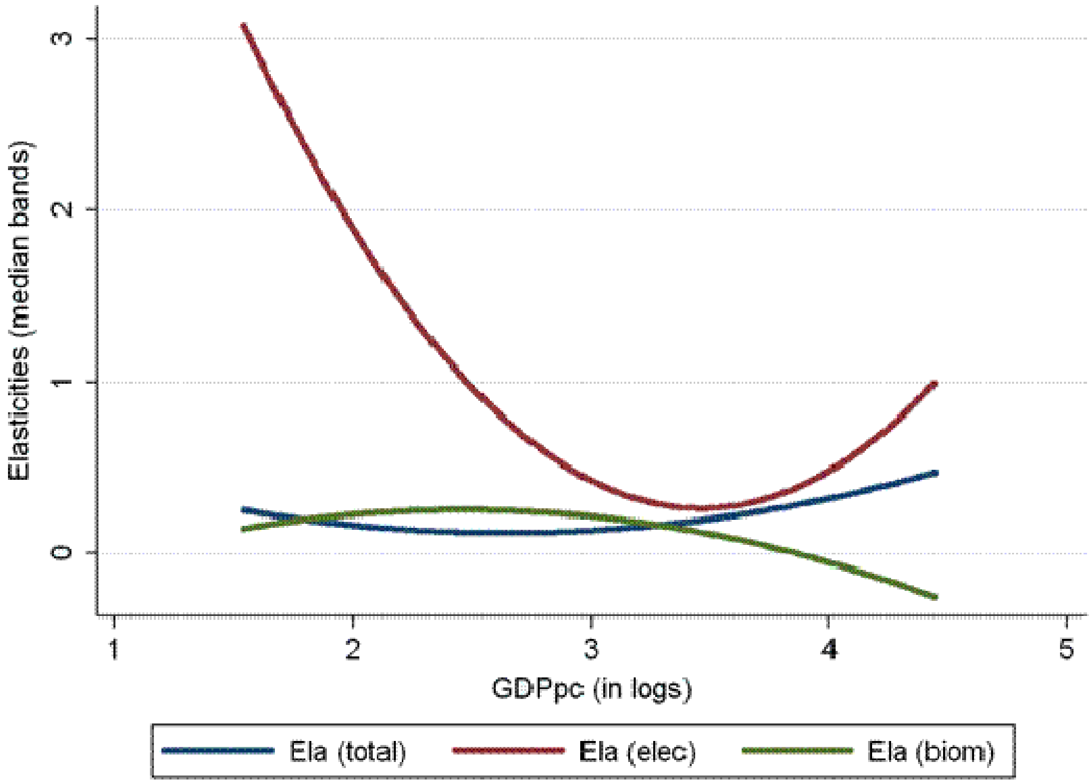
Nicaragua, Bolivia, Guatemala, Jamaica and Paraguay stand out as countries with values above the average, and also maintaining a constant trend throughout the period, without registering the general decreasing trend. Costa Rica, Brazil and Mexico show values slightly below the average. Argentina, Venezuela, Chile, Panama and Uruguay also register elasticity values below the average but with a much sharper decreasing trend at the end of the period, reaching negative values in recent years. Finally, it may be highlighted the evolution of Trinidad, with a more strong decreasing trend and registering negative important values from 1998.

4.3. Evolution of residential energy consumption elasticities by GDPpc levels.

Finally, Figure 3 displays the elasticity values of residential energy consumption (total, electricity and biomass) per capita with respect to GDPpc for each GDPpc level.

Figure 3

Estimated elasticities of residential energy consumption (total, electricity and biomass) per capita with respect to GDPpc by GDPpc level.



Source: Own elaboration.

Considering firstly the total residential energy consumption, the elasticity shows a U shape. Initially, as GDPpc increases the elasticity slightly decreases, although always is positive and being the minimum value reached by this elasticity around 0.12. Anyway, elasticity start to increase as GDPpc does from a GDPpc value close to 2.65 (in logs). From this value, GDPpc increases origin a positive and growing trend in total energy consumption. Therefore, as mentioned above, it is shows that the EKC hypothesis is not supported for total residential energy consumption.

In the case of the residential electricity consumption, although results in Table 7 show that the EKC hypothesis could be supported with a N shape, Figure 3 shows that it does not happen. Initially the elasticity decrease as GDPpc increase, with a strong downward trend. Then, this trend becomes positive from a GDPpc value close to 3.46 (in logs) registering a minimum value for this elasticity around 0.26. So, as in the case of total energy consumption, GDPpc increases origin a positive and growing trend in residential energy consumption.

Nevertheless, the elasticity values show that the ECK hypothesis is supported for the case of the residential biomass consumption, reaching the ECK turning point for a GDPpc value around 3.86 (in logs), when the elasticity values become negatives. Below this value, elasticities are positive, rising until a GDP per capita level close to 2.46. From this value, being the maximum value reached by this elasticity around 0.26, elasticity values start to decrease. Therefore, for values above these levels for GDPpc increases origin a negative and degressive trend in residential biomass consumption.

5. Discussion and conclusions.

Energy consumption is the main cause of CO_2 emissions, so controlling its growth is going to be crucial. However, while emissions growth could be controlled by reducing energy consumption, this reduction could also have negative effects on economic growth. Then, the study and in-depth knowledge of this relationship is considered to be extremely important for the development of effective energy and environmental policies to promote sustainable development.

On the other hand, energy consumption in the residential sector is an area with great potential for implementing energy saving policies, in the sense that the applied energy policies may be more globally-effective in this sector than in others, thus, the analysis of the evolution of residential energy use becomes interesting.

In this study it has been analyzed the relationships between residential energy consumption and income for 22 Latin America and the Caribbean countries in the period 1990-2013. Residential energy environmental Kuznets curves (EKC) have been estimated by taking into account the heterogeneity among the countries by including two control variables: one representing the possible effect of urbanization on residential energy use and the second representing the possible effect of petrol production.

The EKC are estimated for total residential energy consumption, for residential electricity consumption and for biofuels and waste (biomass) energy consumption, and the corresponding elasticities of energy consumption with respect to income have been also calculated for each year and country.

Obtained results show that the EKC hypothesis is confirmed for the residential sector when the biofuels energy consumption is considered. Moreover, the results also show that the turning point has been reached in some countries. Nevertheless, the EKC is not confirmed when electricity or total residential energy consumption is considered. Thus, for total residential energy consumption, the elasticity is always positive, growing also as the income does. For electricity energy consumption, the elasticity is also always positive, since although the elasticity decreases until a threshold, from an per capita income value it begins to grow.

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