REVISTA BRASILEIRA DE ENERGIAS RENOVÁVEIS

THE HYDROELECTRICITY CONSUMPTION AND ECONOMIC GROWTH NEXUS: A LONG TIME SPAN ANALYSIS[1]

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Abstract

The objective of this article analyzes the nexus between hydroelectricity consumption and economic growth in seven Latin American countries in the period from 1966 to 2015, using an auto-regressive distributive lag (ARDL) methodology. The results suggest the existence of feedback hypothesis in short-run, where the hydroelectricity consumption and economic growth are interrelated.

Keywords: Nexus, Hydroelectricity consumption, Economic growth, Latin America, ARDL, Feedback hypothesis.

O CONSUMO DE ENERGIA HIDROELÉTRICA E O NEXO DE CRESCIMENTO ECONÔMICO: UMA ANÁLISE DE LONGO PRAZO

Resumo

O objetivo deste artigo é analisar o nexo entre o consumo de energia hidroelétrica e o crescimento econômico, em sete países da América Latina, no período de 1966 a 2015, utilizando como metodologia o modelo autorregressivo com desfasamentos distribuídos (ARDL). Os resultados sugerem a existência de hipótese de *Feedback* em curto prazo, onde o consumo de energia hidroelétrica e o crescimento econômico são inter-relacionados.

Palavras-chave: Nexo, Consumo de energia hidroelétrica, América Latina, ARDL, Hipótese de *Feedback.*

1. Introduction

The increase of environmental degradation and fossil fuels dependence have led many countries adopted renewable energy sources (RES) in your energy matrix. The RES are defined like energy generation from solar, wind, ocean, hydropower, biomass, geothermal, biofuels, and hydrogen. According to REN 21 (2016) the RES have a participation of 19,2% on global human consumption and 23.7% of their generation electricity in 2015; The RES consumption has participation of 8.9 % coming from biomass, 4.2% as heat energy, 3.9% from hydroelectricity and 2.2 % is electricity from the wind, solar, geothermal, and biomass. Moreover, the RES production has the contribution of 16.6% coming from Hydropower, 3.7 % as Wind, 2.0% from Bio-power, 1.2% from Solar PV, and 0.4 % from Geothermal and ocean.

Our article it is focused on just RES consumption from hydropower, due to the high participation of this source in energy matrix in the countries studied. The hydropower plants are much more reliable, and efficient than non-RES plants (Bildirici,2016). Additionally, according to Margeta and Glasnovic (2011), unlike non-RES, the hydropower energy can continuously produce energy. Furthermore, the hydropower production has the capacity to contribution on development, allocation of increasingly scarce water resources and regional cooperation World Bank (2009).

The correlation between economic growth and RES consumption has constituted a substantial field of research. Different authors have used several methodologies, countries and periods to explain this relationship. For instance, Bildirici (2016) analyses the relationship between economic growth and hydropower energy consumption in Brazil, Finland, France, Mexico, the U.S., and Turkey from 1980 to 2011. The results point to the existence of conservation hypothesis in the countries in the analysis. Apergis and Danuletiu (2014) examines the relationship between RES consumption and economic growth for 80 countries in the period for 1990-2012 and found a positive causality running from RES consumption to economic growth. Ocal and Aslan (2013) examines the RES consumption and economic growth causality nexus in Turkey, for the period between 1990-2010. The authors found the existence of a unidirectional causality running from economic growth to RES consumption. Al-Mulali et al (2013) analysis the 108 countries, low and high income from the period for 1980-2009. The results evidence that in 79% of the countries feedback hypothesis, 19% of the countries neutrality hypothesis and 2% of the countries conservation and growth hypothesis. Others authors have approached this relationship (eg. Yildirim et al ,2012; Tugcu et al ,2012; Salim and Rafiq ,2012; Menegaki ,2011; Bildirici ,2013; Pao and Fu ,2013; Apergis and Payne ,2012; Apergis and Payne,2011; Bowden and Payne ,2010; Menyah and Wolde-Rufael ,2010).

However, these studies have shown several results that do not lead to consensus. Formerly, some studies have indicated the existence of a unidirectional relationship between RES consumption and economic growth and others have appointed to the existence of the bidirectional relationship.

The aim of this study it is to examine the relationship between hydroelectricity consumption and economic growth for Argentina, Brazil, Chile, Colombia, Ecuador, Peru, and Venezuela for the period of 1966-2015 using autoregressive distributed lag (ARDL). This study extends the existing literature specifically on the causal relationship between hydroelectricity consumption and economic growth. Additionally, in the literature, there are few studies which have investigated this relationship in these countries.

This article is organized as follows. In Section 2, was presented the literature review. In Section 3, was presented the model specification and databases used. In Section 4, the empirical results. In Section 5, the discussion. Finally, the conclusions in Section 6.

2. Literature review

The relationship between the RES consumption and economic growth has been explored in several studies in the literature. Moreover, the use of different methodologies, countries and periods have shown several results that do not lead to a consensus about this theme. Then, some studies have indicated the existence of a unidirectional relationship between RES consumption and economic growth vice versa. Others studies have appointed to the existence of a bidirectional relationship between RES consumption and economic growth. Table 1, presents the summary of the literature review with different authors, periods, methodology, countries, and conclusions about this theme.

Table 1. Summary of literature review

Author(s)	Period	Methodology	Country (ies)	Conclusion(s)
Bildirici (2016)	1980-2011	Auto-Regressive Distributed Lag (ARDL	Brazil, Canada, Finland, France, Japan, Mexico, USA, UK, Turkey	There is evidence to support the conservation hypothesis.
Apergis and Danuletiu (2014)	1990-2012	Dynamic Vector Error Correction model (VEC)	Countries in European Union, Western Europe, Asia, Latin America, and Africa	There is a positive causality running from renewable energy to real GDP.
Ocal and Aslan (2013)	1990-2010	Auto-Regressive Distributed Lag (ARDL)	Turkey	There exists a unidirectional causality from renewable energy to real GDP.

Al-mulali et al (2013)	1980-2009	Fully modified OLS tests	108 countries (Low and High-income countries)	In 79% of the countries feedback hypothesis. 19% of the countries neutrality hypothesis and 2% of the countries conservation and growth hypothesis.
Pao and Fu (2013)	1980-2010	Vector Error Correction model (VEC)	Brazil	Feedback Hypothesis.
Bildirici (2013)	1980-2009	Autoregressive Distributed Lag bounds testing (ARDL)	Argentina, Bolivia, Cuba, Costa Rica, El Salvador, Jamaica, Nicaragua, Panama, Paraguay,and Peru	There exists a Feedback causality.
Yildirim et al (2012)	1949-2010	Toda-Yamamoto and Hatemi-J causality tests	U.S.A	Neutrality hypothesis, and Growth hypothesis (causality from biomass-waste-derived energy consumption to economic growth).
Tugcu et al (2012)	1980-2009	Hatemi-J causality tests	G-7 Countries	Neutrality hypothesis for France, Italy, Canada and U.S.A, Feedback hypothesis for England, and Japan, Conservation hypothesis for Germany.

Apergis and Payne (2012)	1990-2007	Panel error correction model	80 countries	Feedback hypothesis in both the short- and long-run.
Salim and Rafiq (2012)	1980-2006	Granger causality	Brazil, China, India, Indonesia, Philippines, and Turkey	There exists a significantly determined by GDP in Brazil, China, India, Indonesia, Philippines and Turkey in long-run, and a bidirectional causality between RES consumption and GDP in short-run.
Menegaki (2011)	1997-2007	Multivariate panel framework	27 European countries	Neutrality hypothesis.
Apergis and Payne (2011)	1980-2006	Panel error correction model	Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama	Feedback hypothesis in both the short- and long-run.
Bowden and Payne (2010)	1949-2006	Toda-Yamamoto long-run causality test	U.S.A	No causality among commercial and industrial RES consumption and GDP; Bidirectional causality among commercial and residential EC and GDP; Unidirectional causality from residential RES consumption to GDP.
Menyah and Wolde-	1960-2007	Granger causality test	U.S.A	Conservation hypothesis.

Rufael (2010)				

Notes: The abbreviations are as follows: Energy Consumption (EC), Renewable Energy Sources (RES), Gross Domestic Product (GDP), Autoregressive Distribution Lag (ARDL),and Vector Error Correction model (VEC).

These studies evidence that the relationship between RES consumption and economic growth in the literature has several conflicts about the results, and direction of causality. Moreover, according to manegaki (2014) and Apergis and Payne (2009) in the literature, there are four hypothesis about this relationship. The first, the growth hypothesis where the energy policies which reduce the energy consumption may have an adverse impact on economic growth, this is due to the high dependence of the economy on energy to growth. Second, the conservation hypothesis, indicate that the growth leads the energy consumption. However, the energy consumption can decrease, without negatively impacting the economic growth. The third hypothesis, the neutrality suggest that the energy consumption has or does not impact on economic growth. Finally, the fourth, the feedback hypothesis suggests that energy consumption and economic growth are interrelated, where there exists a bi-directional causality between them, in other words, they are complements to each other.

3. Model specification and data

This section is divided into three parts. The first one shows the methodology used in the research. The second shows the database used in the investigation. The third the model specification.

3.1 Methodology

The auto-regressive distributed lag (ARDL) model was used, due to the expectative of the existence of some interaction between hydroelectricity consumption and economy growth in Short- and long-run (e.g. Fuinhas, et al. 2016, Marques, et al. 2016, Hashem et al. 2001). This methodology is the best choice, due to the capacity to decomposing the global effects in the short- and long-run in the analysis.

3.2 Data

The article examines seven Latin American countries namely: Argentina, Brazil, Chile, Colombia, Ecuador, Peru, and Venezuela from 1966-2015. The choice of these countries is justified, due to a rapid growth of hydroelectricity consumption in recent years in these countries. Additionally, the choice of time series is acceptable due to the availability of existing data. To analysis, the impact of hydroelectricity consumption on economic growth were used the following variables (see Table 2).

Table 2. Variables in the model

Variables		Description	Source
Gross Domestic Product (GDP)	**LY**	GDP in constant local currency unity (LCU).	The World Bank Data (WBD).
Hydroelectricity consumption	**LH**	Hydroelectricity consumption in Million tonnes oil equivalent.	BP statistical review of world energy.
Carbon Dioxide Emissions (CO_2)	**LCO2**	The million tonnes carbon dioxide emissions from consumption of oil, gas, and coal for combustion-related activities.	BP statistical review of world energy.
Oil consumption	**LO**	Oil consumption in million tonnes.	BP statistical review of world energy.

Notes: The abbreviations are as follows: Local currency unity (LCU); World Bank Data (WBD); Gross Domestic Product (GDP); Carbon Dioxide Emissions (CO_2).

The variables chosen have considered the following criteria (i) they have hydroelectricity consumption in a long period;(ii) they have data available for the entire period. The total population was used to transformed in *per capita* all variables in the model. To control the disparities in population growth among the countries the *per capita* option was used. Consequently, for these variables are estimated that interactions will go beyond of short-run and long. The option to use constant local currency unit allowed to circumvent the influence of exchange rates. To reduction, the fluctuation in the data series, the variables in the model were transformed in natural logarithms. In the econometric analysis were used Stata 14.0 and EViews 9.5 software. The descriptive statistics are presented in Table 3.

Table 3. Descriptive statistics

Descriptive statistics					
	Obs	**Mean**	**Std.Dev**	**Min.**	**Max.**
LY	350	10.5064	3.1210	7.2290	16.2150
LH	350	-15.7066	0.8314	-18.2140	-14.1753
LCO2	350	-13.1042	0.6215	-14.7372	-11.9940
LO	350	-11.4816	0.5246	-12.8661	-10.4676
DLY	343	0.0155	0.0453	-0.1780	0.1504
DLH	343	0.0396	0.1275	-0.6460	0.6730
DLCO2	343	0.0151	0.0617	-0.1850	0.1984
DLO	343	0.0127	0.0634	-0.2020	0.2395

Notes: The Stata command *sum* was used to descriptive statistics.

The cross-section dependence (CSD) is a common characteristic of macro panels. In the literature, there are two types of cross-section dependence: (a) spatial autocorrelation or spatial heterogeneity (Baltagi and Anselin, 2001), and (b) long-range or global independence (Moscone and Tosetti, 2009). According to Fuinhas et al. (2015), the first type of cross-section dependence has into account the distance between the crosses, and the second type occurs when the cross-react in the same way when this occurs provokes correlation between them, irrespective of the geographical distance between countries.

To identify features of series and crosses, and the integration order of the variables, the CSD test (Pesaran,2004) and the second-generation unit root test (CIPS) (Pesaran, 2007) were applied (see Table 4).

Table 4. Cross-section dependence and unit roots tests

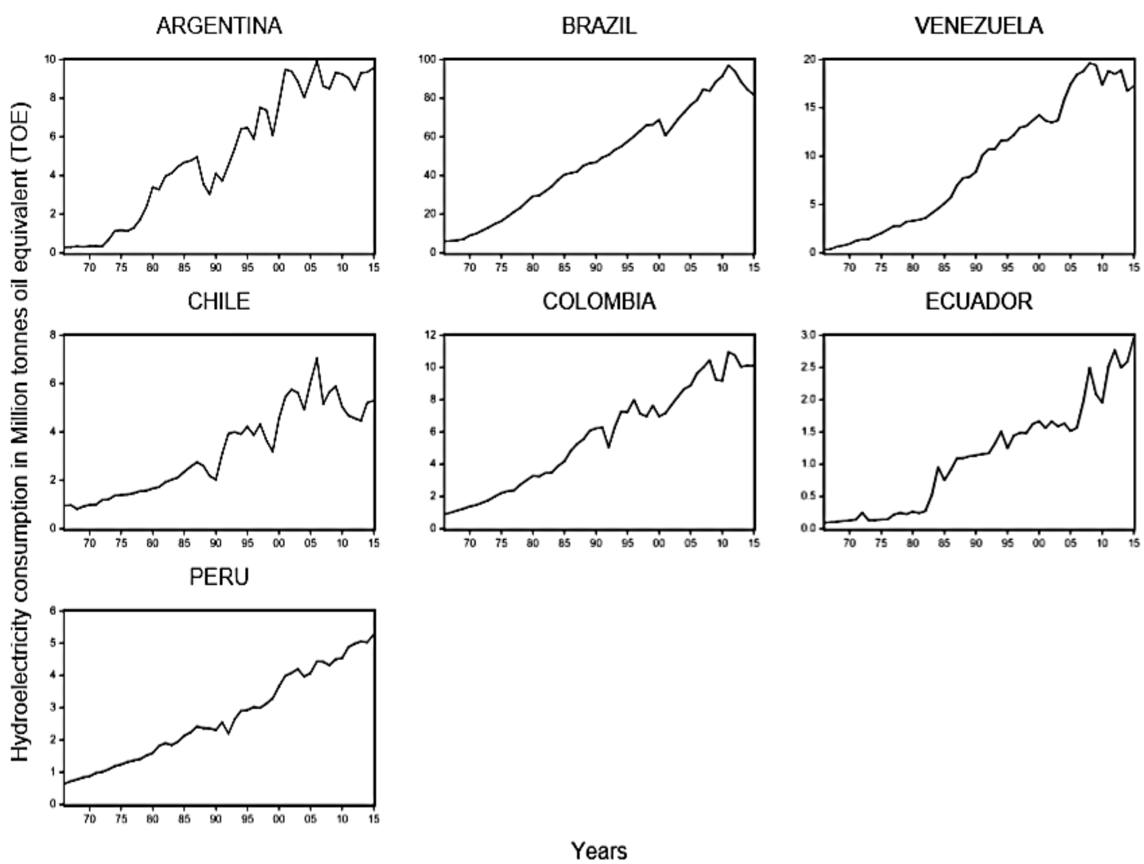
	Cross-section dependence (CSD)				2^{nd} Generation unit root test CIPS (Zt-bar)			
	CD-Test		Corr	Abs (Corr)	Without trend		With trend	
LY	17.64	***	0.544	0.621	-1.056		-1.522	*
LH	30.21	***	0.932	0.932	-3.921	***	-3.546	***
LCO2	15.93	***	0.492	0.495	-1.094		0.004	
LO	3.72	***	0.115	0.470	-0.746		0.037	
DLY	9.24	***	0.288	0.302	-6.392	***	-5.730	***
DLH	3.13	***	0.098	0.169	-10.439	***	-10.019	***
DLCO2	4.07	***	0.127	0.150	-8.663	***	-8.430	***
DLO	3.05	***	0.095	0.140	-7.358	***	-7.243	***

Notes: Pesaran (2004) CD test has N (0,1) distribution, under the H0: cross-section independence ***, * denote significant at 1% and 10% level, respectively. The Stata command *xtcd* was used to achieve the results for CSD; The CIPS test (Pesaran, 2007) has H0: series are I (1); the Stata command *multipurt* was used to compute CIPS test.

The presence of cross-section dependence was identified in all variables in short-and long-run. The second-generation unit root test (CIPS) was used without trend and with the trend, and a lag length (1). The null hypothesis rejection of the CIPS test has H_0: series are I (1). The results of the test indicate that all variables in short-run and long-run (LY and LH) are of order I (1) in other words the variables are stationary. The non-stationary of the long-run variables are due to the shocks that impacted the countries in the analysis.

Figure 1 shows the hydroelectricity consumption charts by cross sections. As shown in Figure 1, the hydroelectricity consumption series are far from stable over time for the most of the countries, reinforcing the necessity to study how this impacts on economic growth in different periods.

Figure 1. The hydroelectricity consumption



Notes: The Eviews 9.5 was used to create the Graph. The Data scalling was selected authomatically by program due to existence of many crosses.

The Variance Inflation Factor (VIF) was used to check the presence of multicollinearity among variables. According to O'Brien (2007), this test indicates the impact of multi-collinearity on the accuracy of estimated regression coefficients. Table 5 reveals the results of matrices of correlation and VIF statistics.

Table 5. Matrices of correlations and VIF statistics

	LY		LH		LCO2		LO
LY	1.0000						
LH	0.0671		1.0000				
LCO2	-0.0569		0.4758	***	1.0000		
LO	-0.2509	***	0.4507	***	0.9345	***	1.0000
VIF			1.29		8.13		7.89
Mean VIF			5.77				
	DLY		**DLH**		**DLCO2**		**DLO**
DLY	1.0000						
DLH	0.0430		1.0000				
DLCO2	0.5075	***	-0.1497	***	1.0000		
DLO	0.4880	***	-0.0746		0.8424	***	1.0000
VIF			1.03		3.54		3.48
Mean VIF			2.68				

Notes: *** denote statically significant at 1%.

The results of VIF points that both the mean VIF of (5.77) to long-run and (2.68) to short-run are low. The low values for the individual VIF reveal that collinearity is not a problem in the model.The Oil consumption has a high correlation with CO_2 emissions in short-and long-run. The possible reason for the high correlation between the variables that the CO_2 emissions is compound with the burn of fossil fuels.

3.3 Model specification

The Unrestricted Error Correction Model (UECM) form of ARDL was used to decomposes the total effects in short-and long-run of variables. To denote the natural logarithms and first differences of variables were used the prefixes (L) and (D). To specify the ARDL model the following equations:

$$LY_{it} = \alpha_{0i} + \delta_{1i} TREND_t + \sum_{j=0}^{k} \beta_{2ij} LH_{it-j} + \sum_{j=0}^{k} \beta_{3ij} LCO2_{it-j} + \sum_{j=0}^{k} \beta_{4ij} LO_{it-j} + \varepsilon_{1it} \quad (1)$$

$$LH_{it} = \alpha_{0i} + \delta_{1i} TREND_t + \sum_{j=0}^{k} \beta_{2ij} LY_{it-j} + \sum_{j=0}^{k} \beta_{3ij} LCO2_{it-j} + \sum_{j=0}^{k} \beta_{4ij} LO_{it-j} + \varepsilon_{2it} \quad (2)$$

Where α_{0i} means the intercept, δ_{1i} is the trend coefficients, $\beta_{2ij,} \beta_{3ij}, \beta_{4ij} \ldots$ are the estimated parameters of variables, and ε_{1it} ε_{2it} are error term of the model.Additionally, in the Equation (1) the variable dependent is LY, and the independents are LH, LCO2, and LO. In the Equation (2) the variable dependent is LH, and the independents are LY, LCO2, and LO. To decompose the dynamic relationship of short-and long-run variables was estimated the fallowing equations:

$$DLY_{it} = \alpha_{0i} + \delta_{31i} TREND_t + \sum_{j=1}^{k} \beta_{32ij} DLH_{it-j} + \sum_{j-1}^{k} \beta_{33ij} DLCO2_{it-j} + \sum_{j=1}^{k} \beta_{34ij} DLO_{it-j} + \gamma_{31i} LY_{it-1} + \gamma_{32i} LH_{it-1} + \gamma_{33i} LCO2_{it-1} + \gamma_{34i} LO_{it-1} + \varepsilon_{3it} \quad (3)$$

$$DLH_{it} = \alpha_{0i} + \delta_{41i} TREND_t + \sum_{j=1}^{k} \beta_{42ij} DLY_{it-j} + \sum_{j-1}^{k} \beta_{43ij} DLCO2_{it-j} + \sum_{j=1}^{k} \beta_{44ij} DLO_{it-j} + \gamma_{41i} LH_{it-1} + \gamma_{42i} LY_{it-1} + \gamma_{43i} LCO2_{it-1} + \gamma_{44i} LO_{it-1} + \varepsilon_{4it} \quad (4)$$

where, α_{0i} denotes the intercept, $\beta_{32ij,} \beta_{33ij}, \beta_{34ij} \ldots$ and $\gamma_{31i}, \gamma_{32i}, \gamma_{33i}, \gamma_{34i,} \kappa = 1, \ldots m$, are the estimated parameters of variables, and ε_{3it} ε_{4it} are the error term of the model. Moreover, in the Equation (3) the variable dependent is DLY, and the independents are DLH, DLCO2, and DLO. In the Equation (2) the variable dependent is DLH, and the independents are DLY, DLCO2, and DLO. The macro panel structure has a long-time span. This advantage allowing the panel unit root test has a standard asymptotic distribution. According to Baltagi (2008), the asymptotic distribution is important to checking the cointegration in the model.

The Random effects (RE) must be tested for the presence of individual effects in the ARDL model. In the RE model, the error term assumes the following form $\mu_i + \omega_{it}$, where the μ_i denotes N-1 country specific effects, and ω_{it} are the independent and identically distributed errors. In conformity, the Equations (3) and (4) (hereinafter model I and model II, respectively) are converted in Equations (5) and (6) by changing ε_{5it} and ε_{6it} for $\mu_i + \omega_{it}$:

$$DLY_{it} = \alpha_{0i} + \delta_{51i}TREND_t + \sum_{j=1}^{k}\beta_{52ij}DLH_{it-j} + \sum_{j-1}^{k}\beta_{53ij}DLCO2_{it-j} + \sum_{j=1}^{k}\beta_{54ij}DLO_{it-j} + \gamma_{51i}LY_{it-1} + \gamma_{52i}LH_{it-1} + \gamma_{53i}LCO2_{it-1} + \gamma_{54i}LO_{it-1} + \mu_i + \omega_{it} \quad (5)$$

$$DLH_{it} = \alpha_{0i} + \delta_{61i}TREND_t + \sum_{j=1}^{k}\beta_{62ij}DLY_{it-j} + \sum_{j-1}^{k}\beta_{63ij}DLCO2_{it-j} + \sum_{j=1}^{k}\beta_{64ij}DLO_{it-j} + \gamma_{61i}LH_{it-1} + \gamma_{62i}LY_{it-1} + \gamma_{63i}LCO2_{it-1} + \gamma_{64i}LO_{it-1} + \mu_i + \omega_{it} \quad (6)$$

where, α_{0i} denotes the intercept, $\beta_{52ij,}\beta_{53ij},\beta_{54ij}\ldots$ and $\gamma_{51i},\gamma_{52i},\gamma_{53i},\gamma_{54i,}\kappa = 1,\ldots m$ are the estimated parameters of variables, and $\mu_i + \omega_{it}$ are the error term of the model. To identify the presence of Random Effects (RE) or Fixed Effects (FE) in the model was used the Hausman test. The null hypothesis of this test points that the best model is the Random effects (RE). Table 6 reveals the coefficients of Hausman test.

Table 6. Coefficients of Hausman test.

Coefficients of Hausman test				
	Fixed (I)	**Random (II)**	**Difference (I-II)**	**S. E**
TREND	0.0012	0.0002	0.0010	0.0003
DLH	0.0427	0.0486	-0.0059	N. A
DLCO2	0.2987	0.2638	0.0350	0.0131
DLO	0.1047	0.1317	-0.0271	0.0149
LY	-0.0631	0.0016	-0.0647	0.0163
LH	-0.0169	-0.0002	-0.0167	0.0054
LCO2	0.0710	0.0028	0.0682	0.0312
LO	-0.0444	-0.0115	-0.0329	0.0214
Test	$\chi^2_8 = 17.89$ *			

Notes: Hausman test. H_0: difference in coefficients not systematic. * denote statistically significant at 10% level, respectively. The Stata command *xtreg* was used to achieve the results for Hausman test. N.A. denotes not available,

The results point to the selection of (FE) model, where the result is significant $\chi^2_8 = 17.89$. The model selected was the (FE) model that evidence the correlation between the variables. The (FE) model evidence a greater suitability for analyzing the influence of variables over time. To back up the parameters statistical significance of the DFE model, a battery of specification tests were applied like: (a) The Modified Wald statistic for groupwise heteroskedasticity; (b) The Pesaran test of cross-section independence;(c) The Wooldridge test, (d) the Breusch-Pagan LM test; (e) Doornik-Hansen test, and (f) Ramsey RESET test.

4. Empirical results

The Westerlund cointegration test (Westerlund, 2007) was used to double-check the cointegration between the variables. The Westerlund test built in four statistical tests, to identification the existence of a normal distribution in the model. The statistics Gt and Ga test the hypothesis of at least one cross-section, having all the variables co-integrated, and the Pt and Pa test the cointegration of the model.

The bootstrapping method was used to provide proper coefficients, standard errors, coefficient intervals and discloses robust critical p-values. Moreover, the Westerlund cointegration test is based on an error correction model, where requires all variables in levels I(I). Table 7 reveals the results of Westerlund cointegration test.

Table 7. Westerlund cointegration test

Statistics	**Westerlund cointegration test**								
	None			**Constant**			**Constant and trend**		
	Value	**Z-value**	**P-value robust**	**Value**	**Z-value**	**P-value robust**	**Value**	**Z-value**	**P-value robust**
Gt	-0.977	1.891	0.898	-1.419	2.284	0.927	-2.037	2.026	0.885
Ga	-1.363	2.731	0.999	-7.449	1.323	0.721	-9.144	2.102	0.905
Pt	-1.374	1.610	0.898	-3.332	1.656	0.836	-4.998	1.615	0.808
Pt	-0.323	1.653	0.964	-5.219	0.904	0.714	-7.735	1.540	0.818

Notes: Bootstrapping regression with 800 reps. H_0: No cointegration; H_1 Gt and Ga test the cointegration for each country individually, and Pt and Pa test the cointegration of the panel. The Stata command *xtwest* (with the constant option) was used.

The null hypothesis of Westerlund cointegration test H_0: Not cointegration between variables. The results of Westerlund cointegration test pointed to not reject the null hypothesis. The possible reason to non-cointegration in the model, it is due to the non-stationarity of variables in long-run (see, Table 4).

The residuals of model confirm the need to control for 1977, 1981, 2002 and 2015 crisis. Thence, was created dummy variables to handle the structural breaks was followed AR2002 VEN2002 and AR2015 in the model I, and ECU1977 and ECU1981 in the model II. The DFE estimator, the DFE robust standard errors, and DFE Driscoll and Kraay (1998) (DFE D.-K) were applied to calculate the semi-elasticities and elasticities.

The battery of specification tests were applied to back up the parameters statistical significance of the DFE model. The Modified Wald statistic of groupwise heteroskedasticity (Greence,2000). This test has as null hypothesis that all variables are homoscedasticity. The Pesaran test of cross-section independence (Pesaran,2004), was used to identification the presence of contemporaneous correlation between the crosses. The null hypothesis of the Pesaran test that the residuals are not correlated. To identification, the serial correlation in the panel-data model was applied the Wooldridge test (Drukker,2003). The null hypothesis of this test is not a first-order correlation between the variables.

The Breusch-Pagan LM test (Greece,2000) for cross-section correlation in the fixed-effect model was used. The null hypothesis points to the presence of cross-section independence. The Doornik-Hansen test (Doornik and Hansen,2008) was applied to check the presence of multivariate normality. The null hypothesis is that the underlying population is normal. The Ramsey RESET test (Ramsey,1969) specifies the powers of explanatory variables. The null hypothesis model has no omitted variables. Table 8 exhibits the short-run semi-elasticities, long-run elasticities for the models DFE, DFE robust, DFE D.-K, and specification tests results of the model I and II.

Table 8. Estimations and specification test results of models

	Model I			Model II		
	Dependent Variable DLY			Dependent Variable DLH		
	DFE (I)	DFE Robust (II)	DFE D.-K. (III)	DFE (IV)	DFE Robust (V)	DFE D.-K. (VI)
Constant	0.7685 **	*	**	-0.6209		
Trend	0.0013 ***	***	***	0.0010		
	Dummy variables					
AR2002	-0.1183 ***	***	***		n.a	
AR2015	-0.2005 ***	***	***		n.a	
VEN2002	-0.1232 ***	***	***		n.a	
ECU1977		n.a		0.3310 ***	***	***
ECU1981		n.a		-0.2106 *	***	***
	Short-run (semi-elasticities)					
DLH	0.0396 **				n.a	
DLCO2	0.2788 ***	*	***	-0.6474 ***		***
DLO	0.1134 *			0.1343		
DLY		n.a		0.4870 ***	*	***
	Long-run (elasticities)					
LH (-1)	-0.2615 ***	***	***		n.a	
LCO2(-1)	1.2169 ***	***	***	0.8505		
LO (-1)	-0.8520 **	***	**	-0.2713		
LY (-1)		n.a		-0.0631		
	Speed of Adjustment					
ECM	-0.0631 ***	*	***	-0.0905 ***	***	***

	Specification test					
Modified Wald Test	χ^2_7 =42.33 ***			χ^2_7 =549.59 ***		
Pesaran test	2.739 ***			-0.133		
The Wooldridge test	F (1,6) =458.850 ***			F (1, 6) =34.594 ***		
Breusch-Pagan LM test	χ^2_{21} =38.153 *			χ^2_{21} = 26.156		
Doornik-Hansen test	χ^2_{24} =3.26e+05 ***			χ^2_{22} =2.21e+05 ***		
Ramsey RESET test	F (3,328) = 12.53 ***			F(3, 329) =3.91 ***		
	Statistics					
N	343	343	343	343	343	343
R^2	0.4255	0.4255	0.4255	0.1985	0.1985	0.1985
R^2_a	0.0017	0.0017	N. A	0.1543	0.1543	n.a
F	F (11,325) = 21.88***	n.a	F (11,6) = 117.85***	F (10,326) = 8.07***	n.a	F (10,6) = 14998.25***

Notes: ***, **, * denote statistically significant at 1%,5%, and 10% level, respectively.; n.a. denotes not available, and were used the *xtreg*, and *xtscc* Stata commands. For H_0 of Modified Wald test: sigma(i)^2 = sigma^2 for all I. Results for H_0 of Pesaran test: residuals are not correlated. Results for H_0 of Wooldridge test: no first-order autocorrelation.

The semi-elasticities were calculated by adding the coefficients of variables in the first differences. Moreover, the elasticities are calculated by dividing the coefficient of lagged independent variable by the coefficient of the lagged independent variable, multiplier by (-1). The results of model I, show that in the short-run elasticities of hydroelectricity consumption exerts a positive impact, where the increase of 1% on hydroelectricity consumption increase the GDP in 0.0396, and long-run elasticities has a negative impact of -0.2615. The Oil consumption has a positive influence in short-run of 0.1134, and in long-run has a negative influence of -0.8520 in GDP, and CO_2 emissions increase the GDP in short-and long-run. For the model II, the short-run elasticities of GDP exert a positive impact, where the increase of 1% of GDP, increase the hydroelectricity consumption in 0.4870, and in long-run elasticities, the GDP does not cause an impact on energy consumption. The Oil consumption does not have an influence on energy consumption in short-and long-run. Finally, the CO_2 reduction the energy consumption in -0.6474 in short-run. In the model, I and II were applied a battery of specification tests to back up the parameters statistical significance of the DFE model. The Modified Wald test, points to the presence of heteroscedasticity. The Pesaran test of cross-section independence, indicate the contemporaneous correlation between the crosses in the model, except in the model II. The Wooldridge test points to the presence of the first-order autocorrelation. The Breusch-Pagan LM test, evidence the presence of cross-section independence in the model I. The Doornik-Hansen test, suggest that the underlying population is normal, and the Ramsey RESET test evidence that in two models no have omitted variables.

5. Discussion

The focus of this study it is analyzed the nexus between hydroelectricity consumption and economic growth using a panel data of countries that have the hydroelectricity consumption. The initial tests prove the existence of cross-sectional dependence, where confirm that these countries share spatial patterns, the phenomena of heteroscedasticity, contemporaneous correlation, and first order autocorrelation cross-sectional dependence in the model.

The creation of dummy variables are due to the identification of shocks in the residuals of model confirm the need to control for 1977, 1981, 2002 and 2015. Thence, were created dummy variables to handle the structural breaks was followed ECU1977, ECU1981, AR2002 VEN2002, and AR2015. The many countries in Latin America suffered several financial and political crises that impacted the region in the period between the 1970s, 2000s, 2008-2009, and 2015. In 1977 and 1981-1982, Ecuador, suffered a chronic economic crisis that unleashed a rising of inflation, and budget deficits, Argentina in 2001-2002 suffered a several financial crises that impacted the consumption of energy, Venezuela in 2002 suffered a political crisis with a military coup takes, and in 2015 Argentina suffered again a new debt crisis. These behaviors reveal the different speeds that the shocks from the crises are experienced by the dependent variable. Economic growth decelerated faster than energy consumption, which explains the positive coefficient dummy in the model II.

Our analysis is focused on the results with the variables DLH and LH in the model I and II. The results showed that in the model I, the short-run elasticities of hydroelectricity consumption exerts a positive impact, where the increase of 1% on hydroelectricity consumption, increase the GDP in (3,96%), and long-run elasticities have a negative impact of (26,15%), and in model II the short-run elasticities of GDP exerts a positive impact, where the increase of 1% of GDP, increase the hydroelectricity consumption in (48,70%) , and in long-run elasticities the GDP does not cause impact on energy consumption. These results suggest the existence of feedback hypothesis in short-run, where the hydroelectricity consumption and economic growth are interrelated because there is a bi-directional causality and hence they are complements to each other. The results achieved reinforce and are consistent with the existing literature (e.g. Al-Mulali et al,2013; Pao and Fu,2013; Bildirici,2013; Apergis and Payne,2012; Salim and Rafiq,2012).

6. Conclusions

The relationship between hydroelectricity consumption and economic growth was analyzed in the article. The study it is focused in seven Latin American countries from 1966-2015 using autoregressive distributed lag (ARDL). The initial tests prove the existence of cross-sectional dependence, where confirm that these countries share spatial patterns, the phenomena of heteroscedasticity, contemporaneous correlation, and first order autocorrelation cross-sectional dependence in the model.

The empirical results complement the existing literature, where the increase of 1% on hydroelectricity consumption, increase the GDP in (3,96%), and long-run elasticities have a negative impact of (26,15%), and in the short-run elasticities of GDP exerts a positive impact, where the increase of 1% of GDP, increase the hydroelectricity consumption in (48,70%) , and in long-run elasticities the GDP does not cause impact on energy consumption. These results suggest the existence of feedback hypothesis in short-run, where the hydroelectricity consumption and economic growth are interrelated.

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