REVISTA BRASILEIRA DE ENERGIAS RENOVÁVEIS

THE NEGATIVE IMPACT OF RENEWABLE ENERGY CONSUMPTION ON CARBON DIOXIDE EMISSIONS: AN EMPIRICAL EVIDENCE FROM SOUTH AMERICAN COUNTRIES[1]

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Abstract

The impact of renewable energy consumption on the carbon dioxide emissions was analyzed for a panel of ten South American countries in a period from 1980 to 2012. The Autoregressive r to decompose the total effect of renewable energy consumption on the carbon dioxide emissions in its short- and long-run components. The results indicate that the consumption of renewable energy reduce the carbon dioxide emissions in -0.0420 % when the consumption of alternative sources increases in 1% in short-run.

Keywords: Renewable energy, environmental, energy economics, econometric.

O Impacto Negativo das Energias Renováveis Sobre as Emissões de Dióxido de Carbono:Uma evidência empírica de países Sul-Americanos

Resumo

O impacto do consumo de energias renováveis sobre as emissões de dióxido de carbono foi analisado em um painel de dez países da América do Sul, durante o período compreendido entre 1980 e 2012. Neste sentido, foi utilizada a metodologia Autoregressive Distributed Lag Panel de forma a decompor o efeito total do consumo de energias alternativas sobre as emissões em seus componentes de curto e longo prazo. Os resultados indicam que o consumo de energia renovável reduz as emissões de dióxido de carbono em -0,0420% quando o consumo de fontes alternativas aumenta em 1% no curto prazo.

Palavras-chave: Energia renovável, meio-ambiente, economia da energia, econométria

1.Introduction

The consequent increase in the level of carbon dioxide emissions (CO_2) caused by fossil fuels consumption has set off an alarm signal worldwide. Additionally, almost all greenhouse gas emissions in the world come from coal 44 %, oil 36 % and 20 % natural gas (IRENA, 2014). The Latin America region saw the CO_2 emissions more than doubling in last three decades, where the region contributes 11% of global CO_2 emissions (Vergara, et al.,2013). Indeed, the region continues a small contributor to the world in emissions (Schipper, et al., 2011). Additionally, an intuitively appealing way to address the challenge of increase of CO_2 emissions is to expand the use of either renewable energy sources (RES) from the wind, solar, geothermal, biomass, hydro to reduce reliance on fossil fuels, and hence the level of CO_2 emissions.

Moreover, the South America region is one of the regions with the largest shares of renewable energy in the energy matrix, due to the contribution of hydropower and bioenergy; Indeed, the most countries in South America region has dynamic markets for solar, photovoltaic, wind, waste, biomass, wave and geothermal; Nowadays, the region has a rapid growth for consumption of alternative energy, and a faster interest in developing of these kind of sources, due to the rapid energy demand, high energy prices, energy security concerns, and the abundance of renewable energy sources like hydropower, wind, solar, waste, biomass, and geothermal in the most countries in region (Fuinhas, et al.,2017).

In literature, several authors have been investigating the impact of renewable energy consumption on the CO_2. One example is, Fuinhas, et al., (2017) investigated the impact of renewable energy policies, primary energy and renewable energy consumption on carbon dioxide emissions for a panel of ten Latin American countries, for a period from 1991-2012, using the Auto-Regressive Distributive Lag (ARDL) model. The authors concluded that the primary energy consumption *per capita* increases the emissions in 0.5822 in short-run and 0.6945 in long-run, renewable energy policies reduce in −0.0415 the CO_2 emissions in long-run, and the renewable energy consumption reduces the emissions in −0.1634 in short-run and −0.1433 in long-run respectively. Zoundi (2017) studied the impacts of renewable energy consumption on CO_2 emissions, and the Kuznets Environmental Curve (EKC) for 25 African countries in a period from 1980-2012. The authors used an ARDL approach to assessing the EKC hypothesis and the impact of renewable energy consumption on emissions. The empirical results point to non-evidence of a total validation of EKC. Moreover, the CO_2 emissions increase with income and the consumption of renewable energy exerts a negative effect on emissions, where the alternative energies are an efficient substitute for the conventional fossil-fuel energy. Jebli and Youssef (2017) utilized a panel cointegration model and Granger causality test to study the relationship between renewable energy consumption, carbon dioxide emissions, Gross Domestic Product (GDP), and Agricultural Value Added (AVA) for a panel of five North African countries in a period from 1980–2011. The results indicated that in short-run the existence of a bidirectional relationship between emissions and agriculture activity, a unidirectional causality between economic growth and renewable energy consumption, and renewable energy to agriculture. In the long-run, there is a bidirectional relationship among agriculture activity and CO_2 emissions, a unidirectional relationship from consumption of renewable energy and agriculture activity and to emissions. Moreover, the estimate results showed that an increase of economic growth or renewable energy increases the emissions, whereas an increase in agricultural activity reduces the CO_2 emissions. Bilgili (2016) researched the existence of Inverted-U shaped the relationship between environmental quality, *per capita* income and alternative energy consumption for 17 Organization for Economic Co-operation and Development (OECD) countries, in the period from 1977-2010, using panel Fully Modified Ordinary Least Squares (FMOLS) and panel Ordinary Least Squares (DOLS) estimations. The results suggest that the GDP *per capita* and GDP *per capita* squared have impacts on CO_2 emissions positively and negatively and renewable energy consumption has a negative impact on CO_2 emissions. Aliprandi, et al., (2016) investigated, the impact of installation of renewable energy systems (e.g. wind and photovoltaic) on CO_2 emissions. The authors found that the reduction of CO_2 emissions are lower than expected considering the amount of energy produced from RES, and is related to the level of RES penetration on energy matrix.

The aim of this study is to answer the following question: Does renewable energy consumption has any impact on carbon dioxide emissions? In order to answer this question, the impact of renewable energy consumption on the CO_2 emissions will be analyzed for ten South American countries namely: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Peru, Paraguay, Venezuela and Uruguay in a period from 1980 to 2012 using Unrestricted Error Correction Model (UECM) form of the Auto-Regressive Distributive Lag (ARDL).

The study of this theme is fundamental to be able to understand the real impact of renewable energy consumption on the emissions in South American countries, and contributes to expanding the scarce literature. Additionally, the choice of South American countries it is due to the region (i) has been a pioneer in designing and implementing specific renewable promotion mechanisms (Fuinhas, et al, 2017); (ii) has experienced rapid growth in alternative energy consumption (See, Figure 1), and is very interested in developing of renewable resources and (iii) has been an important player in the innovation and development of alternative energy sources (Fuinhas, et al, 2017).

This article is organized as follows: Section 2, will present a literature review. Section 3, the material and method used. Section 4, the results and discussions. Finally, the conclusions are shown in Section 5.

2.Literature review

The impact of renewable energy consumption on CO_2 emissions has been the object of a vast body of literature evidencing that this kind of energy has the capacity to reduce the emissions of CO_2. Table 1 presents a brief summary of the literature review, namely of authors, periods, countries, methodology, influence, and main conclusions.

Table 1. Summary of literature review

Author(s)	Period(s)	Country (ies)	Methodology(ies)	Main conclusions
Jebli and Youssef (2016)	1980-2011	Tunisia	Vector Error Correction Model (VECM)	The long-run parameters estimates show that the non-renewable energy, trade and agriculture activity increase CO_2 emissions, whereas renewable energy reduces CO_2 emissions.
Wiebe (2016)	2000-2020	50 countries	MRIO analysis	The PV and the wind in electricity production) have a higher contribution (−15% and −20%) to consumption-based emissions.
Jaforullah and King (2015)	1960-2007	U. S. A	Vector Autoregressive (VAR) model	The results indicate that CO_2 emission levels are negatively related to the use of renewable energy sources.
Jebli and Youssef (2015)	1980-2009	Tunisia	ARDL model	The renewable energy consumption affects negatively the emissions of CO_2.
Robalino-López, et al., (2015)	1980-2050	Venezuela	Hodrick–Prescott (HP) methodology	The consumption of renewable energy sources to reduce the CO_2 emissions by 15%.
Özbuğday and Erbas (2015)	1971-2009	Non-OECD countries	Ordinary Least Squares (DOLS) methodology	The renewable energy in total energy is related to an average decrease of 0.11 % of CO_2 emissions over the long term.

Qi, et al., (2014)	2000-2010	China	China-in-Global Energy Model (C-GEM)	The introduction of renewable electricity over the period 2010 to 2020, overall CO_2 emissions intensity falls by a modest 2%.
Shafiei and Salim (2014)	1980-2011	OECD countries	STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model	The empirical results show that renewable energy consumption has a negative and significant effect on CO_2 emissions, whereas non-renewable energy consumption has a positive and statistically significant effect on CO_2 emissions in the long-run.
Farhani and Shahbaz (2014)	1980–2009	10 The Middle East and North Africa (MENA)	Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) methodology	There is a long-run bidirectional causality between renewable and non-renewable electricity consumption and CO_2 emissions. Moreover, the renewable and non-renewable electricity consumption increase CO_2 emissions.
Apergis, et al., (2010)	1984-2007	19 developed and developing countries	Vector Error Correction Model (VECM)	The renewable energy did not contribute to reductions in emissions.
Menyah and Wolde-Rufael (2010)	1960-2007	U. S	VAR model	the use of renewable energy sources has not helped to mitigate US CO_2 emissions.

Notes: The abbreviations are as follows: United States of America (U.S.A), Organization for Economic Co-operation and Development (OECD); Middle East and North Africa (MENA); Vector Error Correction Model (VECM); Fully Modified Ordinary Least Squares (FMOLS); Dynamic Ordinary Least Squares (DOLS); Vector Autoregressive (VAR); Multi-Regional Input-Output (MRIO).

The literature provides evidence the consumption of alternative energies have contributed to the mitigation of greenhouse gas emissions.

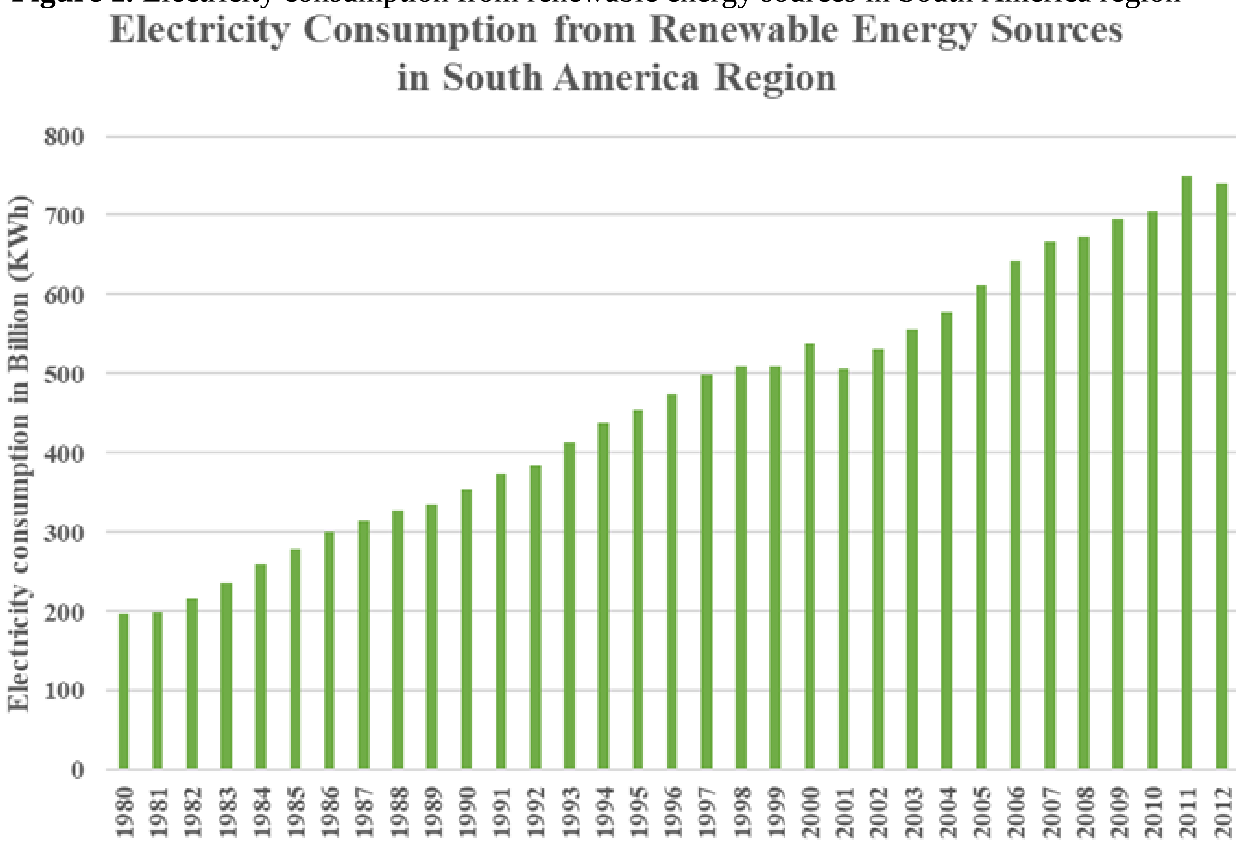
3. Material and method

This section is divided into two parts. In the first one, it will be presented the material used in this research. The second section contains the method.

3.1 Material

To analyze the impact of renewable energy consumption on greenhouse gas emissions, it was utilized the data, from 1980 to 2012, of ten South American countries namely: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Peru, Paraguay, Venezuela and Uruguay. All the approached South America region has increased their renewable energy consumption and as such, they are highly relevant to this research (see Figure 1) below.

Figure 1. Electricity consumption from renewable energy sources in South America region



Notes: the chart was created by author. This chart was created by use of data from Energy Information Administration (EIA).

As can be seen in Figure 1, the consumption of renewable energy sources have been faster growth in the last three decades in South America region. Moreover, to analysis the impact of the RES consumption on CO_2 emissions were used the following variables (see Table 2).

Table 2. Variables in the model

Variables		Description	Source
Carbon Dioxide Emissions (CO_2)	**LCO2**	From the consumption of fossil fuels energy in million metric tons.	Energy Information Administration (EIA).
Renewable Energy Consumption	**LRE**	Net Generation in Billion Kilowatt-hours, from renewable sources, include hydro, wind, geothermal, solar, biomass and waste.	Energy Information Administration (EIA).
Gross Domestic Product (GDP)	**LY**	GDP in constant local currency unity (LCU).	The World Bank Data (WBD).
Petroleum consumption	**LP**	Total Petroleum consumption in quadrillion Btu.	Energy Information Administration (EIA).

Notes: The abbreviations are as follows: British thermal unit (Btu).

The countries are selected taken the following criteria for the variables: (i) they have been renewable energy consumption for a long period; and (ii) they have data available for the entire period for CO_2 emissions, GDP, and petroleum consumption. To transform all variables in *per capita* was used the total population. The variables in *per capita* help us control the disparities in population growth among the countries (Fuinhas, et al.,2017). The GDP in local currency units (LCU) reduces the influence of exchange rates (Koengkan,2017). Hereafter the prefixes (L) and (Δ) denotes natural logarithm and first-differences of variables respectively. Moreover, in the econometric analysis was performed using EViews 9.5 and Stata 14.0 software.

The best econometric practices strongly recommend testing for the presence of heterogeneity, that which could arise a long-time span used. The long-time spans exacerbate the potential occurrence of a panel with parameter slope heterogeneity and presence of cross-section dependence (CSD). On the CSD issue, the literature identifies two main types of dependence between crosses: (i) spatial autocorrelation or spatial heterogeneity (Baltagi and Anselin, 2001), and (ii) long-range or global interdependence (Moscone and Tosetti, 2009). The first type of CSD takes into account the distance between crosses, while the second type occurs when the crosses react in the way, i.e. in a very similar mode to the same, then this provokes correlation between them, irrespective of the geographical distance between countries (Fuinhas, et al.,2015).

Moreover, this correlation mirrors occurrence of common, unobserved factors that affect the countries' variables over time. In South American countries, it is expected the presence of CSD. Indeed, when the CSD it is not controlled, it can produce both biased estimates and a severe identification problem (Eberhardt and Presbitero,2013; Fuinhas, et al.,2017). Table 2 reveals the descriptive statistics and the cross-section dependence of variables.

Table 2. Descriptive statistics and cross-section dependence test

	Descriptive statistics					**Cross-section dependence (CSD)**			
	Obs	Mean	Std.Dev	Min.	Max.	CD test		Corr.	Abs(Corr)
LCO2	330	-13.2598	0.6694	-14.8064	-11.9527	17.43	***	0.452	0.485
LRE	330	2.8335	1.4397	-0.3930	6.1292	30.60	***	0.794	0.794
LY	330	10.839	3.1129	7.2290	16.1225	28.97	***	0.752	0.752
LP	330	-1.1399	1.3553	-3.9932	1.7905	32.42	***	0.841	0.841
ΔLCO2	320	0.0116	0.0777	-0.2776	0.2650	3.58	***	0.094	0.181
ΔLRE	320	0.0503	0.1860	-0.6120	1.5046	1.99	**	0.052	0.188
ΔLY	320	0.0131	0.0449	-0.1531	0.1504	15.70	***	0.414	0.414
ΔLP	320	0.0250	0.0715	-0.2553	0.2868	4.26	***	0.112	0.195

Notes: Pesaran (2004) CD test has N (0,1) distribution, under the H_0: cross-section independence. ***, **, denotes statistically significant at 1%, and 5% levels respectively. The Stata command *xtcd* was used to achieve the results for CSD.

The presence of cross-section dependence in the variables both in levels and in first-differences was confirmed by CDS-test. The presence of CSD evidences interdependence between the cross-sections that the countries share common shocks (Fuinhas, et al., 2017).

3.2 Method

The Autoregressive Distributed Lag (ARDL) in the form of Unrestricted Error Correction Model (UECM) was applied to analyze the impact of RES consumption on the emissions. The ARDL model has a capacity to decompose the total effect of a variable into its short and long-run components (e.g. Fuinhas, et al. 2017; Koengkan,2017). Moreover, this model is consistent with efficient estimations and parameters inferences based on the standard test (Srinivasan, et al., 2012). The general UECM form of the ARDL model used in this empirical analysis follows the specification of the Equation (1):

$$LCO2_{it} = \alpha_{0i} + \theta_{1i}TREND_t + \sum_{j=1}^{k}\phi_{11ij}LRE_{it-j} + \sum_{j=0}^{k}\phi_{12ij}LY_{it-j} + \sum_{j=0}^{k}\phi_{13ij}LP_{it-j} + \varepsilon_{1it} \quad (1)$$

where α_{0i} denotes the intercept, θ_{1it} is the trend and $\phi_{11ij,}\phi_{12ij\ldots}$ are the estimated parameters, and ε_{1it} is the error term. The Equation (1) can be transformed in an equivalent dynamic specification. The equation (2) that allows to capture the short- and the long-run effects of independent variables on the dependent one.

$$\Delta LCO2_{it} = \alpha_{0i} + \theta_{21i}TREND_t + \sum_{j=1}^{k}\phi_{22ij}\Delta LRE_{it-j} + \sum_{j-1}^{k}\phi_{23ij}\Delta LY_{it-j} + \sum_{j=1}^{k}\phi_{24ij}\Delta LP_{it-j} + \gamma_{21i}LCO2_{it-1} + \gamma_{22i}LRE_{it-1} + \gamma_{23i}LY_{it-1} + \gamma_{24i}LP_{it-1} + \varepsilon_{2it} \quad (2)$$

where α_{0i} denotes the intercept, θ_{2it} is the trend and $\phi_{21ij,}\phi_{22ij\ldots}\gamma_{21i,}\gamma_{22i\ldots}$ are the estimated parameters, and ε_{2it} is the error term.

The variance inflation factor (VIF) provides an indication the impact of multi-collinearity on the accuracy of estimated regression coefficients (O'Brien,2007). The VIF-test and correlation test was used to check the presence of multicollinearity and correlation coefficients between variables (see Table 3).

Table 3. Matrices of correlations and VIF statistics

	LCO2	**LRE**	**LY**	**LP**
LCO2	1.0000			
LRE	0.3396 ***	1.0000		
LY	-0.2729 ***	0.1024	1.0000	
LP	0.6780 ***	0.7427 ***	-0.2780 ***	1.0000
VIF		2.90	1.41	3.11
Mean VIF		2.47		
	ΔLCO2	**ΔLRE**	**ΔLY**	**ΔLP**
ΔLCO2	1.0000			
ΔLRE	-0.2264 ***	1.0000		
ΔLY	0.3664 ***	0.0091	1.0000	
ΔLP	0.6637 ***	-0.1898 ***	0.4037 ***	1.0000
VIF		1.05	1.21	1.25
Mean VIF		1.17		

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

The results of VIF-test points that the mean VIF of (2.47) to long-run and (1.17) to short-run are low. The low VIF-test statistics support that the multicollinearity is not a great concern in the model (Fuinhas, et al.,2017). The panel data technique allows to control for heterogeneity of the cross. When is analyzed many variables are necessary more information, variability, degrees of freedom and efficiency and thus, less collinearity than is generally present in the time series approaches (Klevmarken,1989; Hsiao,2003; Fuinhas, et al.,2015).

The first-generation unit root tests of LLC (Levin, Lin, and Chu, 2002), ADF-Fisher (Maddala and Wu, 1999), and ADF-Choi (Choi, 2001), and second-generation unit root test CIPS of Pesaran (2007) were used to obtain the order of integration of variables. Table 4 shows the results of unit root tests.

Table 4. Unit roots tests

	1st Generation test						2nd Generation unit root test CIPS (Zt-bar)			
	LLC		ADF-Fisher		ADF-Choi					
	Individual intercept and trend						Without trend		With trend	
LCO2	-1.2109		29.8091	*	-0.9332		-0.802		-0.812	
LRE	-3.3297	***	42.4013	***	-2.9146	***	-1.600	**	-3.354	***
LY	-2.5527	***	30.6570	**	-0.9030		-0.237		-0.627	
LP	-2.3364	***	19.6462		-0.5193		-0.417		1.173	
ΔLCO2	-8.4104	***	109.419	***	-8.0681	***	-8.817	***	-8.499	***
ΔLRE	-8.8996	***	109.200	***	-8.2202	***	-9.505	***	-7.997	***
ΔLPY	-6.2199	***	73.6748	***	-5.8164	***	-6.130	***	-5.318	***
ΔLP	-7.2684	***	90.9046	***	-6.8320	***	-8.153	***	-7.465	***

Notes: ***, **, * denote statistically significant at 1%, 5% and 10% level, respectively. The null hypotheses are as follow: the LLC test the unit root (common unit root process), this unit root test controls for individuals effects, individual linear trends, has a lag length 1, and Newey-West automatic bandwidth selection and Bartlett kernel were used; the ADF-FISHER and ADF-Choi test the unit root (individual unit root process), this unit root test controls for individual effects, individual linear trends, has a lag length 1, the first generation test follows the option "individual intercept and trend", which was decided after a visual inspection of the series. The Eveiws 9.5 was used in the calculus of the first-generation tests. The CIPS test (Pesaran, 2007) has H_0: series are I(1). The Stata command *multipurt* was used to compute CIPS test.

The LLC, ADF-Fisher, and ADF-Choi used individual linear trends, and a lag length (1). The first-generation test follows the option "individual intercept and trend", which was decided after a visual inspection. The null hypothesis of the LLC, ADF-Fisher, and ADF-Choi tests it is that the variables are I(1). In the CIPS-test (Pesaran,2007) without trend and with trend, and a lag length (1). The null hypothesis of CIPS-test it is that the variables are are I (1). The results of the two test indicate that the difference of variables and the variable in short-run LRE are series of order I(I).

The macro panel structure has a long-time span, where the panel unit root test has a standard asymptotic distribution, which is important when checking for cointegration (Baltagi,2008). The presence of individual effects must be tested against Random Effects (RE) in the model. Indeed, 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} is the independent and identically distributed errors. The Equation (2) converted in Equation (3) by changing ε_{2it} for $\mu_i + \omega_{it}$:

$$\Delta LCO2_{it} = \alpha_{0i} + \theta_{21i} TREND_t + \sum_{j=1}^{k} \phi_{22ij} \Delta LRE_{it-j} + \sum_{j-1}^{k} \phi_{23ij} \Delta LY_{it-j} + \sum_{j=1}^{k} \phi_{24ij} \Delta LP_{it-j} + \gamma_{21i} LCO2_{it-1} + \gamma_{22i} LRE_{it-1} + \gamma_{23i} LY_{it-1} + \gamma_{24i} LP_{it-1} + \mu_i + \omega_{it}. \quad (3)$$

The Hausman test of the Random Effects (RE) against the Fixed Effects (FE) specification to identify the presence of RE or FE in the model was used. This test has the null hypothesis that the best model is RE. Table 5 reveals the coefficients of Hausman test.

Table 5. Coefficients of Hausman test.

Coefficients of Hausman test				
	Fixed (I)	**Random (II)**	**Difference (I-II)**	**S. E**
TREND	-0.0023	0.0002	-0.0025	0.0007
ΔLRE	-0.0420	-0.0498	0.0078	0.0047
ΔLY	0.2792	0.2252	0.0540	0.0045
ΔLP	0.6371	0.6399	-0.0028	0.0072
LCO2	-0.2427	-0.0090	-0.2337	0.0380
LRE	-0.0064	-0.0042	-0.0023	0.0070
LY	0.1220	-0.0004	0.1224	0.0344
LP	0.1504	0.0064	0.1440	0.0360
Test	$\chi^2_8 =$ 38.63***			

Notes: Hausman test. H_0: difference in coefficients not systematic. *** denote statistically significant at 1% 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 $\chi^2_8 =$ 38.63. 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.

The FE model is appropriate for analyzing the influence of variable over time, even as it removes all time-invariant features from the independent variables (Fuinhas, et al.,2017). Additionally, this allows a great evaluation of the net effect of the explanatory variables. Indeed, in the macro panel, the presence of long time spans and cross-section is strongly advise testing for parameters panel heterogeneity.

The Mean Group (MG) or Pooled Mean Group (PMG) estimators could be applied to checks the heterogeneity of model (Fuinhas, et al., 2015; Fuinhas, et al.,2017). These estimators require a large number of cross-sections (N) and time of observations (T) (Blackburne III and Frank,2007). The MG is a flexible technique, which creates regressions for each individual and then computes for all individuals an average coefficient (Pesaran et al., 1999). This estimator is consistent in long-run average, while in presence of slope homogeneity the model it is not efficient (Pesaran et al., 1999).

The PMG is an estimator that makes restrictions among cross-section in long-run parameters, then not in short-run and in adjustment speed term, whereas the PMG estimator is more efficient and consistent in the existence of homogeneity in the long-run than MG estimator (Fuinhas, et al.,2017).

Moreover, a battery of model specification tests were performed: (i) Modified Wald test (Greene,2000) to identified the existence of groupwise heteroscedasticity in the residuals of a fixed effect regression model;(ii) Breusch and Pagan Langrarian Multiplier test of independence (Breusch and Pagan, 1980) to measure whether the variances across individuals are correlated;(iii) Pesaran test of cross-section independence (Pesaran,2004), to identify the existence of contemporaneous correlation among cross-sections. The null hypothesis of this test specifies that the residuals are non-correlated and it follows a normal distribution; (iv) Wooldridge test (Wooldridge,2002) to check the existence of a serial correlation.

4. Results and Discussion

The MG and PMG estimations were tested against dynamic fixed effects (DFE). Additionally, in the presence of heteroskedasticity contemporaneous, first order autocorrelation and cross-section dependence in the context of a long-time span, the Driscoll ad Kraay (1998) estimator need to be apply because this estimator generates robust standard errors for several phenomena in the sample errors (Fuinhas et al.,2015; Fuinhas, et al.,2017). In addition, the DFE estimator, DFE robust and DFE Driscoll and Kraay (DFE D.-K) were computed. The battery of specification tests like the modified Wald test for groupwise heteroscedasticity, Pesaran (2004) for cross-section independence, Breusch-Pagan Langrarian Multiplier test to evidences the variances across individuals are correlated, and Wooldridge test for autocorrelation in panel data.

Table 6 evidences, the estimation results of the MG, PMG, DFE models, the outcomes of the Hausman test, the semi-elasticities which were calculated by adding the coefficients of variables in the first-differences, and elasticities which are calculated by dividing the coefficient of lagged independent variable by the coefficient of the lagged independent variable, multiplier by (-1) for the models DFE, DFE robust and DFE D.-K, and finally reveals the results of model specification tests.

Table 6. Estimation results

(Dependent Variable DLCO2)									
	Heterogeneous estimator				**Fixed effects**				
	MG (I)		**PMG (II)**		**Coefficients**		**FE (III)**	**FE Robust (IV)**	**FE D.-K. (V)**
Constant	-10.7926	***	-7.2669	***	-4.3155	***	***	***	***
Trend	-0.0015		-0.0032	***	-0.0023	***	***	*	***
	Short-run (semi-elasticities)								
ΔLRE	-0.1343	***	-0.1252	***	-0.0420	**	***		**
ΔLY	0.3741	***	0.3877	***	0.2792	***	***	***	***
ΔLP	0.5228	***	0.5641	***	0.6371	***	***	***	***
(Dependent Variable LCO2)									
	Long-run (elasticities)								
LRE (-1)	-0.0976		-0.0412		-0.0263				
LY (-1)	0.3014		0.5022	***	0.5025	***	**	**	**
LP (-1)	0.4374	***	0.5497	***	0.6196	***	***	***	***
	Speed of adjustment								
ECM	-0.6713	***	-0.4093	***	-0.2427	***	***	***	***
	Hausman test				**Specification test**				
	MG vs PMG		**PMG vs DFE**		**Modified Wald test**		**Pesaran test**		**Wooldridge test**
	$\chi^2_9 =$ -0.43		$\chi^2_9 =$ 0.00***		$\chi^2_{10} = 574.85$***		1.348		F (1,9) = 82.006***

Notes: ***, **,* denote statistically significant at 1% ,5% and 10% levels respectively; Hausman results for H_0: Difference in coefficients not systematic; ECM denotes error correction mechanism; the long-run parameters are computed elasticities; the Stata commands *xtpmg*, and Hausman (with the sigmamore option) were used;In the fixed effects 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 Hausman test points that the DFE model is homogeneous and it is an appropriate estimator. Indeed, the DFE, DFE robust and DFE D.-K estimators points to presence of long-memory of the variables, because the Error Correction Mechanism (ECM) term it is statistically significant at 1% levels, and has a negative signal (Koengkan,2017). Thus, the existence of long-memory of variables confirms the presence of Grande causality between variables to CO_2 emissions.

Indeed, the ARDL model in form of UECM, allows us to discriminate the Grander causality between short and long-run (Fuinhas, et al.,2017). In fact, the ARDL model in form of UECM model it is like the Cointegration and Error Correction version of Granger causality (Jouini 2015; Mehrara,2007). The ARDL methodology shows robust due to the presence of endogeneity of variables, and the ECM parameter is statistically significant at 1 % and negative. Thus, when an ECM parameter is statistically significant, it is identical the realization of Granger causality test (Fuinhas, et al.,2017). Furthermore, the error correction version of Granger Causality and Cointegration can ensure that both the magnitude of the effects and causality are revealed by elasticities of themselves.

The results show that the semi-elasticities (short-run) which are the first-differences of renewable energy consumption, decrease the emissions of CO_2 in -0.0420 %, when the consumption of alternative energies increase 1 %, whereas the elasticities (long-run) which are the logarithms of the variable does not cause any impact on emissions. The negative impact of renewable energy consumption on CO_2 emissions, it is in line with several authors that studied the Latin American countries (e.g. Fuinhas, et al., 2017; Robalino-López, et al.,2015; Sheinbaum, et al.,2011).

Certainly, decrease of CO_2 emissions by alternative energy consumption in short-run is due to the investments in renewable energy sources that are the result of the availability of enormous biodiversity and the abundance of renewable sources (e.g. hydropower, wind, solar, geothermal and biomass) in most Latin American countries (Fuinhas, et al.,2017). Moreover, Sheinbaum, et al. (2011) points that the development of bio-ethanol production in the Latin American countries is an effective substitute for crude-oil-derived diesel, where their production reduces the CO_2 emissions, as well as other environmental impacts and land competition with food production.

Then, the non-impact of renewable energy consumption on CO_2 emissions in long-run is due to the possible inefficiency of renewable energy policies that does not improve the development of alternative energies in South America region in long-run.

The economic growth of South American countries increase the emissions in 0.2792 % in short-run and 0.5022 % in long-run. These results are in line with several authors that studied the Latin American countries (e.g. Fuinhas, et al, 2017; Pablo-Romero and Jesús, 2016; Said and Hammami, 2015; Al-Mulali, et al., 2015; Robalino-López, et al.,2015; Zillo, 2012; Zilio and Recalde ,2011).

Indeed, the positive impact of economic growth on CO_2 emissions can be caused by the globalization and free trade agreements that increase the economic growth and industrialization of South American countries and consequently intensification of environmental degradation (Zillo,2012). Moreover, other authors like Grossman and Krueger (1991) points that the increase of environmental degradation by economic growth in South American countries, it is directly related to the structure of the economy, where the environmental degradation tends to increases when there is a change from an agricultural to an industrialized economy. Besides that, Zilio and Recalde (2011) complement, that the income growth and the transition from rural to industrial activities in Latin American countries produce higher environmental degradation, conversely through of industrialization process, where the economy evolves to a higher development stage. Finally, Pablo-Romero and Jesús (2016) conclude that the average rate of economic growth in Latin America region has increased significantly since 2004, which is due to the economic expansion promoted and led by exports of large economies in the region like Argentina, Brazil, Colombia, Peru, and Venezuela, and consequently increase the environmental degradation in these countries.

The petroleum consumption in short-run increases the emissions in 0.5641 % and 0.5497 % in long-run. The positive effects of petroleum consumption on emissions in South American countries are confirmed by several authors (e.g. Fuinhas, et al, 2017; Pablo-Romero and Jesús, 2016; Robalino-López, et al.,2015; Zilio and Recalde,2011).

Surely, the influence of petroleum consumption on emissions it is due to the presence of fossil fuels in the energy matrix in some countries of Latin America region are major fossil fuel producers, such as Argentina, Brazil, Colombia, Ecuador, Mexico, Peru and Venezuela, and great imports such as the Central American countries and Chile (Fuinhas, et al.,2017). Besides that, Zilio and Recalde (2011) include that economic activity in Latin American countries requires a direct or indirect form of consumption of fossil fuels, heat or electricity to operate. Thus, the energy consumption in the region turns out to be responsible for almost 77% of the total CO_2 emissions.

Finally, the battery of model specification tests to back up the parameters statistical significance of the DFE model was applied. The modified Wald-test points to the presence of heteroscedasticity. The Pesaran test of cross-section independence indicates to the non-existence of correlation between the crosses. The Wooldridge-test points to the presence of the first-order autocorrelation, and the Breusch-Pagan LM-test can not be applied due to correlation matrix of residuals are singular.

5. Conclusions

The impact of renewable energy consumption on CO_2 emissions was analyzed in this article. The study focused in ten South American countries from 1980-2012 using auto-regressive distributed lag (ARDL). The initial tests proved the existence of cross-sectional dependence, where confirm that these countries share spatial patterns, the phenomena of heteroscedasticity, contemporaneous correlation, first order autocorrelation cross-sectional dependence, and the existence of Granger causality.

Indeed, the battery of model specification tests like modified Wald-test pointed to the presence of heteroscedasticity. The Pesaran test of cross-section independence indicates to the non-existence of correlation between the crosses. The Wooldridge-test points to the presence of the first-order autocorrelation, and the Breusch-Pagan LM-test can not be applied due to correlation matrix of residuals are singular.

The results showed that the semi-elasticities of renewable energy consumption, decrease the emissions in -0.0420 %, when the consumption of alternative energies increase 1 %, whereas the elasticities do not cause an impact on emissions. These results could be a consequence of investments in renewable energy sources that are the result of the availability of enormous biodiversity and the abundance of renewable sources. Moreover, the non-impact of renewable energy consumption on CO_2 emissions in long-run is due to the possible public policies inefficiency that does not improve the development and consumption of alternative energies.

In addition, the economic growth of South American countries increase the emissions in

0.2792 % in short-run and 0.5022 % in long-run, and the petroleum consumption has a positive effect of 0.564 %1 in short-run and 0.6196 % in long-run. These results are due to income growth, economic structure change, and industrialization process in South American countries, and also the great fossil fuels dependency in some countries in the region.

Thus, these evidence points to the necessity of creating public policies more efficiency for promoting the investments, production, and consumption of renewable energy sources, where the impact of alternative energy sources on emissions is small. Indeed, the development of policies more efficient could contribute to increasing of economic competitiveness, create added value, assist in the development of endogenous resources, generate jobs, and makes the renewable energy sources more attractive than conventional alternatives.

Moreover, these findings indicate the needs for policymakers to change the current energy matrix to a more sustainable, due to some countries in South America are dependents of fossil fuels like Argentina, Brazil, Colombia, Ecuador, Mexico, Peru, Venezuela and Chile, as well as for the need to develop new renewable policies, planned to promotes economic growth and environmental sustainability.

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