THE ENERGY-ECONOMIC GROWTH NEXUS IN LATIN AMERICAN AND THE CARIBBEAN COUNTRIES: A NEW APPROACH WITH GLOBALISATION INDEX

O NEXO DE CRESCIMENTO ECONÔMICO-ENERGÉTICO NOS PAÍSES DA AMÉRICA LATINA E DO CARIBE: UMA NOVA ABORDAGEM COM O ÍNDICE DE GLOBALIZAÇÃO

LE LIEN ÉNERGIE-CROISSANCE ÉCONOMIQUE DANS LES PAYS D'AMÉRIQUE LATINE ET DES CARAÏBES: UNE NOUVELLE APPROCHE AVEC L'INDICE DE MONDIALISATION

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Abstract
This article inaugurates the study of the energy-economic growth nexus with a new approach with the introduction of globalisation index, in ten Latin American and the Caribbean countries from 1971-2014. The Autoregressive Distributed Lag (ARDL) and the Granger causality Wald test were used as a methodology. The empirical results pointed to the existence of a bidirectional relationship between economic growth and consumption of renewable energy, a unidirectional relationship from consumption of fossil to economic growth, and a bidirectional relationship between globalisation and consumption of renewable energy. That these results help the local governments develop new policies with the purpose of increases the consumption of renewable energy and reduces environmental degradation while promoting development.

Keywords: Energy Economics; Environmental Economics; Latin America; Energy-Growth Nexus.

Resumo

Este artigo inaugura o estudo do nexo de crescimento econômico-energético com uma nova abordagem com a introdução do índice de globalização em dez países da América Latina e do Caribe de 1971 a 2014. Utilizou-se como metodologia o Atraso Distribuído Autoregressivo (ARDL) e o teste de Wald de causalidade de Granger. Os resultados empíricos apontaram para a existência de uma relação bidirecional entre crescimento econômico e consumo de energia renovável, uma relação unidirecional do consumo de fósseis para crescimento econômico e uma relação bidirecional entre globalização e consumo de energia renovável. Que esses resultados ajudem os governos locais a desenvolver novas políticas com o objetivo de aumentar o consumo de energia renovável e reduzir a degradação ambiental, promovendo o desenvolvimento.

Palavras-chave: Economia de energia; Economia ambiental; América latina; Nexo de Crescimento Energético.

Abstrait

Cet article inaugure l'étude du lien croissance énergie-économie avec une nouvelle approche avec l'introduction de l'indice de mondialisation, dans dix pays d'Amérique latine et des Caraïbes de 1971 à 2014. La méthodologie du décalage temporel réparti autorégressif (ARDL) et du test de causalité de Granger de Wald a été utilisée. Les résultats empiriques ont mis en évidence l'existence d'une relation bidirectionnelle entre croissance économique et consommation d'énergies renouvelables, d'une relation unidirectionnelle allant de la consommation de combustibles fossiles à la croissance économique, ainsi que d'une relation bidirectionnelle entre mondialisation et consommation d'énergie renouvelable. Que ces résultats aident les gouvernements locaux à élaborer de nouvelles politiques visant à augmenter la consommation d'énergie renouvelable et à réduire la dégradation de l'environnement tout en favorisant le développement.

Keywords: Économie de l'énergie; Environnement Economique; Amérique latine; Nexus énergie-croissance.

1.Introduction

The energy demand in Latin American countries has increased in tandem with economic growth in the last forty years. Among 1971 to 2013 the Gross Domestic Product (GDP) of Latin American countries had an annual growth rate of 3.0%, while the energy demand was 5.4% (BALZA et al., 2016). Indeed, in 1971, the GDP per capita in US dollar was 668.60 US$, and in 2013, it was 10,157.60 US$ (WORLD BANK DATA, 2018). The energy used in Latin America region has more than tripled over the past forty years, where 1971 was used 248 million tonnes of oil equivalent (MTOE) and in 2014 was 848 MTOE an increase of 8% over the period (BALZA et al., 2016). Additionally, it is projected for the region an expand by more than 80% through 2040, with an average annual rate of 2.2%, reaching over 1.538 MTOE (BALZA et al., 2016). The increase of GDP and energy consumption are related to the rapid process of economic and trade openness caused by several economic reforms and political transitions that have occurred in the last forty years and are still occurring in the Latin America region.

This process openness started in the 1970s in a period in that the Latin America society were nationalistic and conservative and that not accepting the economic and social changes, where was required by the globalisation process (ROJAS, 2007). Indeed, during this process of globalisation, the region entered in a period of low economic growth, punctuated in some countries with high inflation (HAGGARD and KAUFMANN, 2008). The first experience with trade liberalisation in the region was Chile in the 1970s that had made this economy one of the most open in the entire world. In the 1983 Costa Rica set out on gradual economic liberalisation. Then in 1985, Bolivia and Mexico stated several liberalisation programs of their own. Moreover, in the early 1990s, other countries joint to this movement, such as Argentina, Brazil, Peru, and Venezuela. Even Colombia that in 1990 that started the regular program of economic liberalisation and completed in 1992 (PINTO and LEHERA, 1993).

Moreover, these processes of liberalisation can be represented by numerous integration associations that have been formed since the 1970s — for example, the Andean community that was created in 1969 by Bolivia, Chile, Colombia, Ecuador, and Peru. In 1972 Venezuela was added, while in 1976 Chile withdrew from this association, and in 2006 Venezuela exit. In 1989 the Latin American Integration was created. An excellent example of Latin America's effort to enter globalisation was the creation of Mercosur in 1991. This free trade association includes Argentina, Brazil, Uruguay, Paraguay, and Venezuela. This latter country was excluded due to the political and economic crisis that occurs since 2014 (THEODORE, 2015).

The central questions of this article are: What is the nexus between economic growth and consumption of energy in the Latin American countries? - Is there causality between energy consumption and globalisation in the countries of this region? – How do these causalities work in the Latin America region? To answer these questions the nexus between economic growth and consumption of energy, as well as the globalisation and energy will be investigated in ten countries from Latin America for the period from 1971 to 2014. The Autoregressive Distributed Lag (ARDL) form of Unrestricted Error Correction Model (UECM) and Granger causality Wald test were used as a methodology to the realisation of this study.

Indeed, this investigation is pioneering in the literature for the following reasons such as (i) the inclusion of the globalization index in this investigation; (ii) the use of ARDL in form of UECM and Granger causality Wald test as methodologies; and (iii) the new approach using the Latin American countries, given that this group are not addressed in the literature that approaches this topic; and (iv) this investigation explains more fully how the variables are related if compared with other studies that investigated the same relationship.

This investigation is relevant for the following reasons such as (i) it is necessary to comprehend how the variables interact in the Latin American countries; (ii) will help the policymakers develop appropriate energy policies to reduce the dependence of fossil fuels and their consumption;(iii) the empirical findings of this study will contribute to scarce literature that investigates the nexus between economic growth and consumption of energy and globalization in the Latin America region.

This investigation is organised as follows. Section 2 presents the literature review. Section 3 presents the data and method. Section 4 presents the results. Section 5 presents the discussions. Section 6 presents the robustness check. Section 7 will present the conclusions and policy implications.

2. Literature review

The nexus between economic growth and consumption of energy has been explored by several authors (e.g., ANG, 2007; ACARAVCI and OZTURK, 2010; APERGIS and PAYNE, 2010; APERGIS et al., 2010; CARAIANI et al., 2015; DESTEK and ASLAN, 2017; FUINHAS and MARQUES, 2011; FUINHAS et al., 2017; HATZIGEORGIOU et al., 2011; KAIS and MBAREK, 2017; KOENGKAN, 2017c; KOENGKAN, 2017d; LEE, 2006; MENEGAKI, 2011; MENEGAKI and OZTURK, 2013; MENEGAKI et al., 2017; NARAYAN and POPP, 2012; SEBRI and BEN-SALHA, 2014; TUGCU et al., 2012), while few authors have explored the relationship between consumption of energy and globaliation (e.g., SOYTAS et al., 2007; SHAHBAZ et al., 2013; KOENGKAN, 2017a; SHAHBAZ et al., 2017; YAZDI and SHAKOURI, 2017; WHEELER, 2000; RAHMAN and MIAH, 2017).

Although, several authors have used different countries, regions, methodologies, and also variables to clarify the relationship between economic growth and consumption of energy as well as globalisation and consumption of energy the best approach remains without a solution. What conclusions have been reached by the energy economics literature regarding the nexus between economic growth and consumption of energy? What conclusions have been reached about the relationship between the consumption of energy and globalisation? To answer these questions, this present literature review was divided into two parts to discuss the most important studies that approach the nexus between consumption of energy and economic growth, and the relationship between energy and globalisation.

2.1. Consumption of energy and economic growth nexus

In the literature, several conclusions about this topic have been reached. For instance, some authors found the absence of causality between economic growth and consumption of energy (e.g., LEE, 2006; MENEGAKI, 2011; MENEGAKI and OZTURK, 2013).

LEE (2006) explored the relationship between economic growth and consumption of energy in G-11 countries in the period from 1961 until 2001. The author used as the methodology the Vector autoregression (VAR) model. So, the empirical results indicate the presence of the neutrality hypothesis in the model. MENEGAKI (2011) studied the relationship between economic activity and consumption of renewable energy in 27 European countries in a multivariate panel framework over the period 1997–2007 using a model the random effect. The author found that the empirical results do not confirm the presence of causality between consumption of renewable energy and economic activity. MENEGAKI and OZTURK (2013) investigated the same nexus in 26 European countries in a period from 1975 to 2009 using a two-way fixed effects model and including the variables such as carbon dioxide emissions (CO_2), capital, consumption of fossil fuels. The empirical results indicate the absence of causality between economic activity and consumption of energy.

Indeed, a group of scholars found the unidirectional causality among consumption of energy and economic growth (e.g., ANG, 2007; ACARAVCI and OZTURK, 2010; CARAIANI et al., 2015; DESTEK and ASLAN, 2017; HATZIGEORGIOU et al., 2011; KAIS and MBAREK, 2017; NARAYAN and POPP, 2012). ANG (2007) examined the dynamic relationship between CO_2 emissions, consumption of energy, and economic growth in France using the vector error-correction model (VECM) in a period among 1960–2000. The results indicate the existence of unidirectional causality running from the consumption of energy to economic growth in the short-run. ACARAVCI and OZTURK (2010) explored the relationship between CO_2 emissions, consumption of energy, and economic growth using ARDL bounds testing for nineteen European countries. The outcomes indicate the presence of unidirectional causality between the variables. CARAIANI et al. (2015) investigated the relationship between the consumption of energy and economic growth in the context of emerging European countries for the period from 1980 to 2013. The Granger causality test was used as a methodology. So, the empirical results confirm the existence of the neutrality hypothesis between the variables. DESTEK and ASLAN (2017) studied in emerging economies the nexus between consumption of renewable and non-renewable energy and economic growth from 1980 to 2012. The bootstrap panel causality that allows both cross-section dependency and country-specific heterogeneity across countries was used as methodology. The empirical results indicate the presence of a unidirectional relationship. HATZIGEORGIOU et al. (2011) examined the nexus between consumption of energy, CO_2 emissions, Gross Domestic Product (GDP) in Greece from 1977 to 2017. The Johansen cointegration tests and Granger causality test was used as a method. Consequently, the empirical results indicate that there is a unidirectional among the selected time series.

KAIS and MBAREK (2017) investigated for the period from 1980 to 2012, three North African countries the relationship between consumption of energy, economic growth, and emissions of CO_2. The authors used as the methodology the Granger causality test and VECM model was used. The results indicated the presence of a unidirectional relationship between economic growths to the consumption of energy in the short-run. NARAYAN and POPP (2012) analysed in 93 countries the relationship between consumption of energy and real GDP for the period from 1980 to 2006. The authors used the methodology of the Granger causality test. So, the empirical results indicated that the increase of 5% in the level of consumption of energy caused the increase of real GDP in Western Europe, Asia, Latin America, Africa, and G6 countries.

Moreover, there is another group of scholars that discovered the existence of bidirectional causality between economic and consumption of energy (e.g., APERGIS and PAYNE, 2010; APERGIS et al. 2010; FUINHAS and MARQUES, 2011; TUGCU et al., 2012; SEBRI and BEN-SALHA, 2014; KOENGKAN, 2017c; KOENGKAN, 2017d; MENEGAKI et al., 2017). For example, APERGIS and PAYNE (2010) examined the nexus between consumption of renewable energy and economic growth for a panel data of twenty OECD countries over the period between 1985-2005. Additionally, the heterogeneous panel cointegration test and Granger causality test were used as methodology. Indeed, the empirical results indicated the presence of a long-run relationship between the consumption of renewable energy, GDP, gross fixed capital formation, and the labour force. The Granger causality test indicates a bidirectional causality between consumption of renewable energy and economic growth both in short- and in long-run.

Moreover, the same authors (i.e. APERGIS et al., 2010) studied the relationship between emissions of CO_2, consumption of nuclear and renewable energy consumption and finally the economic growth for a group of 19 developed and developing countries for the period from 1984 to 2007. The authors utilised nothing less than a panel error correction model and Granger causality test as a method. So, the long-run estimates indicate that there is a significant negative relationship among consumption of nuclear energy and emissions of CO_2 and a positive relationship between emissions of CO_2 and consumption of renewable energy. The Granger causality test indicates the existence of bidirectional causality between consumption of renewable energy and economic growth. FUINHAS and MARQUES (2011) examined the nexus between consumption of non-renewable energy and economic growth in Portugal in a period of 1965 to 2009 using the ARDL model. The results indicate the existence of a bidirectional relationship between economic growth to the consumption of energy and energy to economic growth.

TUGCU et al. (2012) examined the causal relationships among consumption of renewable and non-renewable energy and economic activity in G7 countries in a period from 1980 to 2009. The ARDL bounds testing was used as methodology. Moreover, the results of this investigation indicated the presence of bidirectional causality between all variables in the model. SEBRI and BEN-SALHA (2014) investigated in the BRICS countries over the period from 1971 to 2010, using the ARDL bounds testing and also VECM as the methodology the relationship between economic growth, consumption of renewable energy, CO_2 emissions, and trade openness. Empirical results point to the existence of long-run equilibrium relationships between the variables. The VECM results indicated the presence of a bidirectional relationship between economic growth and consumption of renewable energy, suggesting the feedback hypothesis.

Moreover, these results indicate that the consumption of renewable energy stimulating the economic growth in the BRICS countries. KOENGKAN (2017c) utilised the vector autoregressive (VAR) as a methodology to investigate the relationship between the consumption of biofuels and economic growth in Brazil during the period from 1990 to 2015. The results indicate the presence of a bidirectional relationship between the variables in the model.

Moreover, the same author KOENGKAN (2017d) investigated in seven countries from the Latin America region the causality between consumption of hydroelectricity energy and economic growth using the ARDL in the form of the UECM model. The author found the existence of a bidirectional relationship between economic growth and consumption of hydroelectricity. Finally, MENEGAKI et al. (2017) studied the energy-economic growth nexus in 26 European countries for the period from 2000 to 2012 and using the ARDL in the form of the UECM model. The results indicate the existence of feedback hypothesis in the model.

Based on these results of the literature review about the nexus between the consumption of energy and economic growth, this investigation has four hypotheses to answer our central question:

Neutrality Hypothesis (1): Absence of relationship whatsoever. The absence of a relationship between economic growth and consumption of energy is due to the conservative policies that reduce energy consumption. However, this reduction in energy consumption does not impact economic growth. This phenomenon happens principally in developing economies with high energy efficiency;

Conservation Hypothesis (2): The unidirectional relationship from economic growth to consumption of energy. This relationship occurs, when the conservation policies do not impact the economic growth is due to that these economies are not dependent on energy to grow;

Growth Hypothesis (3): The unidirectional relationship from consumption of energy to economic growth. The consumption of energy exerts a positive impact on economic activity, and any conservative policies for energy will impact economic growth;

Feedback Hypothesis (4): The bidirectional relationship between consumption of energy and economic growth. The conservative policies can cause an adverse effect on economic activity and *vice versa*.

2.2. Globalisation and consumption of energy relationship

Concerning the relationship between globalisation and consumption of energy, many conclusions about this topic have been reached. For instance, the globalisation influences foreign direct investments (FDI) and consequently encourages trade and economic activity. Moreover, this process has impacted the transfer of technology from developed to developing countries and consequently increase their energy consumption (SOYTAS et al., 2007). Several authors reached this conclusion. For example, SHAHBAZ et al. (2013) that studied the relationship between consumption of energy and globalisation in Netherlands and Ireland using a quantile autoregressive distributed lag (QARDL) model in a quarterly data over the period from 1970Q1 to 2015Q4. The authors discovered that globalisation has a positive correlation with the consumption of energy in the long-run for the two countries. Moreover, there is a robust bidirectional relationship between the variables in the long-run. KOENGKAN (2017a) examined the influence of globalisation on primary energy consumption in the Latin American and Caribbean region in a period of 1991 to 2012. The auto-regressive distributed lag (ARDL). The empirical results indicated that the increase of 1% of globalisation exerts a positive impact of 0.4449% above the consumption of primary energy. This increase is due to the globalisation exerts a positive effect on total factor productivity and economic growth and consequently increase the energy demand.

SHAHBAZ et al. (2017) examined the relationship between globalisation, consumption of energy, and economic growth for 25 developed economies for the period from 1970 to 2014. The VAR model was utilised as the method. The empirical founds pointed out that, most countries in the study, the globalisation increases energy consumption. In the UK and USA, this relationship is negative. Moreover, the causality tests indicated the existence of a unidirectional relationship between globalisation to the consumption of energy. YAZDI and SHAKOURI (2017) studied the nexus between consumption of renewable energy, primary energy consumption, economic growth, capital fixed formation, trade openness, urbanisation, and globalisation for Iran in 1991Q1-2014Q4. The ARDL bounds testing was used. The results indicated the existence of positive bidirectionality between all variables of the model.

On the other hand, other authors (e.g., WHEELER, 2000) pointed out that the globalisation increases the investments in energy-efficient production and consumption technologies in the countries where the high environmental regulations are present. It makes that the link between the consumption of energy and globalisation be negative. Indeed, some authors reached this conclusion. For instance, RAHMAN and MIAH (2017) investigated in a panel data of 26 countries the impact of energy sources production on globalisation for the period between 1990 and 2010. The authors use as the methodology the panel least squares to identify the effect of independent variables to be related to globalisation. The results indicated that coal and oil production hurts globalisation. This result is due to the consumption of this kind of sources reduces the level of globalisation. Moreover, the authors too found the existence of a negative relationship between the consumption of renewable energy and globalisation. It found to indicate that some countries have not been able to materialise the benefits of international trade as well as clean energy technology.

Based on these founds of the literature review about the relationship between globalisation and consumption of energy, this investigation has three hypotheses to answer our central question:

Reduction Hypothesis (5): The unidirectional relationship from globalisation to consumption of energy. This relationship occurs, when the globalisation increases the investments in energy-efficient production and consumption technologies, consequently reducing the consumption of energy;

Growth Hypothesis (6): The unidirectional relationship from globalisation to consumption of energy. The globalisation exerts a positive impact on economic activity and consequently in energy consumption;

Feedback Hypothesis (7): The bidirectional relationship between consumption of energy and globalisation.

In literature review was identified several gaps that need to be filled. The first gap is related to the sample of countries employed, where the most previous investigations only focused their analysis on developed countries. In the literature review of this investigation show that few numbers of studies have examined the nexus between economic growth and consumption of energy as well as globalisation and energy in emerging or developing countries and few number studies that have focused on the Latin American region. The second gap concerns the methodology, where the majority studies only focused in following methodologies: ARDL bounds testing, VECM model, Granger causality, and PVAR model, leaving aside the ARDL in the form of UECM model. The third gap is the nonrealization of robustness check in the model.

Finally, it is essential to emphasise that this present literature review has discussed the most important studies that approach these topics. This literature review focused on providing a comprehensive review of the related studies evidencing their key findings. The next section will evidence the data and method of this study.

3. Data and method

The first subsection describes the variables that will be used in this investigation, and the second subsection will evidence the method.

3.1. Data

Ten countries from Latin America and the Caribbean region (i.e. Argentina, Brazil, Bolivia, Chile, Colombia, Costa Rica, Mexico, Nicaragua, Peru, and Uruguay) were selected to examine the nexus between consumption of energy and economic growth. The period from 1971 to 2014 was used in this investigation. Latin America and the Caribbean is a region with a population estimated of more than 639 million in 2014, with a combined nominal Gross Domestic Product (GDP) of 5.573,397 million USD, and a GDP purchasing power parity (PPP) of 7.531,585 million USD (WORLD BANK DATA, 2018). Moreover, the choice of this region has the attraction of being a group of countries that: (a) has experimented a rapid economic growth; (b) has registered fast growth in the consumption of energy, principally in the renewable sources; and (c) has undergone an accelerate trade and economic openness process.

These former motives justified the choice of this region and the necessity to carry out this investigation. Therefore, after the presentation of the object of this and also the justifications that led to the choice of this region, the variables that will be used in this study are presented. Table 1, shows the variables that will be used in this study, the definition and sources.

Table 1. Definition and sources of variables

Variables	Definition	Source
CO_2	CO_2 emissions (metric tons *per capita*)	World Bank Data (WBD)
DOMS	Domestic credit provided by the financial sector (% of GDP)	*Idem*
EXP	Exports of goods and services (constant 2010 US$)	*Idem*
FOSSIL	Electricity production from oil, gas and coal sources (% of total)	*Idem*
GDP	GDP *per capita* (constant 2010 US$)	*Idem*
GLOBAL	Index Globalization that includes (Globalisation in the economic, social and political)	KOF Globalization Index
NATU_RENTS	Total natural resources rents (% of GDP)	*Idem*
REN	Electricity production from renewable sources, excluding hydroelectric (% of total)	*Idem*

Notes: The links for sources are available in references.

The variables (GDP and CO_2 emissions) were transformed in *per capita* values, using the total population of each country with the purpose of moderate the effects of population disparity between the Latin American countries (KOENGKAN, 2018). So, after the choice of variables, it is necessary to show the technique that will be used in this investigation. To this end, in the next subsection, will be shown the method.

3.2 Method

The Autoregressive Distributed Lag (ARDL) in the form of Unrestricted Error Correction Model (UECM) will be used to analyse the nexus between energy-economic growth in Latin America and the Caribbean countries. This method, according to MENEGAKI et al. (2017), produces consistent estimates for in the long-run that are asymptotically normally distributed. Additionally, the same authors point out that the only constraint is to assure that the series is most integrated of order one. Other authors such as PESARAN et al. (2001) complements that the ARDL model is robust in the presence of endogeneity between the variables, given that it is free of serial correlation presence. These same authors add yet that this method is flexibility in the presence of long memory if compared with Fully Modified OLS (FMOLS), the Dynamic OLS (DOLS) and Generalized method of moments (GMM) that require that the variables are unequivocally I(1). In the econometric literature, the ARDL model as Dynamic Fixed Effects estimator allows the differentiation between the short-and long-run Granger causality, between the variables (MENEGAKI et al., 2017). This causality can be seen by Error Correction Model (ECM) as the cointegration and error correction version of Granger Causality (e.g., MENEGAKI et al., 2017; FUINHAS et al., 2017; KOENGKAN, 2018). The ARDL model follows the following general equation for the GDP, globalisation and energy production:

$$\begin{aligned} LnGDP_{it} = a_i + Trend_t + \sum_{j=1}^{k} \delta_{2it} LnDOMS_{it-j} + \sum_{j=1}^{k} \delta_{3it} LnCO_{2_{it-j}} \\ + \sum_{j=1}^{k} \delta_{4it} LnEXP_{it-j} + \\ \sum_{j=1}^{k} \delta_{5it} LnNATU\_RENTS_{it-j} + \sum_{j=1}^{k} \delta_{6it} LnGLOBAL_{it-j} + \sum_{j=1}^{k} \delta_{7it} LnFOSSIL_{it-j} \\ + \sum_{j=1}^{k} \delta_{8it} LnREN_{it-j} + \varepsilon_{1it} \end{aligned} \qquad (1)$$

$$LnGLOBAL_{it} = a_i + Trend_t + \sum_{j=1}^{k} \delta_{2it}\, LnDOMS_{it-j} + \sum_{j=1}^{k} \delta_{3it}\, LnCO_{2_{it-j}} + \sum_{j=1}^{k} \delta_{4it}\, LnEXP_{it-j} + \sum_{j=1}^{k} \delta_{5it}\, LnNATU\_RENTS_{it-j} + \sum_{j=1}^{k} \delta_{6it}\, LnREN_{it-j} + \sum_{j=1}^{k} \delta_{7it}\, LnFOSSIL_{it-j} + \sum_{j=1}^{k} \delta_{8it}\, LnGDP_{it-j} + \varepsilon_{2it} \quad (2)$$

$$LnREN_{it} = a_i + \sum_{j=1}^{k} \delta_{2it}\, LnDOMS_{it-j} + \sum_{j=1}^{k} \delta_{3it}\, LnCO_{2_{it-j}} + \sum_{j=1}^{k} \delta_{4it}\, LnEXP_{it-j} + \sum_{j=1}^{k} \delta_{5it}\, LnNATU\_RENTS_{it-j} + \sum_{j=1}^{k} \delta_{6it}\, LnGDP_{it-j} + \sum_{j=1}^{k} \delta_{7it}\, LnFOSSIL_{it-j} + \varepsilon_{3it} \quad (3)$$

$$LnREN_{it} = a_i + Trend_t + \sum_{j=1}^{k} \delta_{2it}\, LnDOMS_{it-j} + \sum_{j=1}^{k} \delta_{3it}\, LnCO_{2_{it-j}} + \sum_{j=1}^{k} \delta_{4it}\, LnEXP_{it-j} + \sum_{j=1}^{k} \delta_{5it}\, LnNATU\_RENTS_{it-j} + \sum_{j=1}^{k} \delta_{6it}\, LnGLOBAL_{it-j} + \sum_{j=1}^{k} \delta_{7it}\, LnFOSSIL_{it-j} + \varepsilon_{4it} \quad (4)$$

where “Ln” denote variables in the natural logarithms, α_i denotes intercept, $\delta_{2it}...\delta_{8it}, k = 1, \cdots, m$ are estimated parameters, as $\varepsilon_{1it}...\varepsilon_{4it}$ are the error term. Moreover, the equations 1 and 2 correspond the models I and II, and equations 3 and 4, the model's III and IV, respectively. After that, Eqs. (1, 2, 3, and 4), can be re-parameterised into the general UECM form, Eqs. (5, 6, 7, and 8), to decompose the dynamic relationship of variables in the short- and long-run, as follows:

$$DLnGDP_{it} = a_i + Trend_t + \sum_{j=1}^{k} \gamma_{2it}\, DLnDOMS_{it-j} + \sum_{j=1}^{k} \gamma_{3it}\, DLnCO_{2_{it-j}} + \sum_{j=1}^{k} \gamma_{4it}\, DLnEXP_{it-j} + \sum_{j=1}^{k} \gamma_{5it}\, DLnNATU\_RENTS_{it-j} + \sum_{j=1}^{k} \gamma_{6it}\, DLnGLOBAL_{it-j} + \beta_{1it} LnGDP_{it-1} + \beta_{2it} LnFOSSIL_{it-1} + \beta_{3it} LnREN_{it-1} + \beta_{4it} LnEXP_{it-1} + \beta_{5it} LnGLOBAL_{it-1} + \varepsilon_{5it-1} \quad (5)$$

$$DLnGLOBAL_{it} = a_i + Trend_t + \sum_{j=1}^{k} \gamma_{2it}\, DLnNATU\_RENTS_{it-j} + \beta_{1it} LnGLOBAL_{it-1} + \beta_{2it} LnREN_{it-1} + \beta_{3it} LnCO_{2_{it-1}} \varepsilon_{6it-1} \quad (6)$$

$$DLnREN_{it} = a_i + \sum_{j=1}^{k} \gamma_{1it}\, DLnFOSSIL_{2_{it-j}} + \beta_{1it} LnREN_{it-1} + \beta_{2it} LnGDP_{it-1} + \varepsilon_{7it-1} \quad (7)$$

$$DLnREN_{it} = a_i + \sum_{j=1}^{k} \gamma_{2it}\, DLnDOMS_{it-j} + \sum_{j=1}^{k} \gamma_{3it}\, DLnFOSSIL_{2_{it-j}} + \beta_{1it} LnREN_{it-1} + \beta_{2it} LnGDP_{it-1} + \beta_{3it} LnGLOBAL_{it-1} + \varepsilon_{8it-1} \quad (8)$$

where "D" and "Ln" denote first-differences and the natural logarithms of raw variables, α_i means intercept, $\gamma_{2it} \ldots \gamma_{6it} \beta_{2it} \ldots \beta_{5it}, k = 1, \cdots, m$ are estimated parameters, as $\varepsilon_{5it-1} \ldots \varepsilon_{8it-1}$ are the error term. Additionally, the equations 5 and 6 correspond the models I and II, and equations 7 and 8, the model's III and IV respectively. So, before the ARDL regression, it is necessary to apply the preliminary tests to check the characteristics of variables (KOENGKAN, 2018). To this end, the preliminary tests were computed, such as:

a) Cross-section Dependence (CSD-test) to check the presence of cross-section dependence in the variables of the model. The null hypothesis is the presence of CSD in the variables (PESARAN, 2004);
b) Variance Inflation Factor (VIF) to verify the existence of multicollinearity among the variables;

c) 2nd generation unit root test (CIPS-test) (PESARAN, 2007) to checks the existence of unit root in the variables. The null hypothesis rejection is that the variable is I(1);
d) 2nd generation cointegration test of WESTERLUND (2007) to checks the presence of cointegration. The null hypothesis is the non-presence of cointegration. Additionally, the Westerlund cointegration test requires that all variables of the model be I(1) (e.g., FUINHAS et al., 2017; KOENGKAN, 2018).

After the realisation of preliminary tests, it is necessary to apply the specification tests with the purpose of check the characteristics of the ARDL model. Considering this, the following specifications tests were applied, such as:

a) Friedman test, to verify the presence of cross-sectional dependence in the ARDL model (FRIEDMAN, 1937). So, the null hypothesis rejections of this test are the model's residuals are not correlated and follows a normal distribution;
b) Breush and Pagan Lagrangian Multiplier test, to measure whether the variances across the individuals are correlated (BREUSH and PAGAN, 1980);
c) Wooldridge test (WOOLDRIDGE, 2002) to verify the existence of serial correlation in the model;
d) Modified Wald test (GREENE, 2002) to check the presence of groupwise heteroscedasticity in the model.

A panel vector autoregression (PVAR) will be used both to assesses the Granger causality between the variables (via Wald test), and to check the robustness of the model. The PVAR model was created by HOLTZ-EAKIN et al. (1988) as a substitute to multivariate simultaneous equation model. Indeed, this model according to ANTONAKAKIS et al. (2017) has several advantages such as: (i) this model is advantageous to study the nexus between the variables; (ii) this model was created to address the endogeneity problem among the variables, where the endogeneity is one most challenge in the research that investigated the relationship between the variables; (iii) this model can determine whether the effects of variables are in the short-, long-run or both; and (iv) allows to include country fixed-effects that capture the time-invariant components and global time effects that affect all countries in the same period. The PVAR model is shown in Eq.9:

$$y_{it} = y_{it-1}e_1 + y_{it-2}e_2 + \ldots + y_{it-p+1}e_{p-1} + y_{it-p}e_p + x_{it}b + u_{it} + \varepsilon_{it} \,, \qquad (9)$$

where, y_{it} is the vector of dependent variables that are the variables in the first differences (DLnREN, DLnFOSSIL, DLnGDP, and DLnGLOBAL). Indeed, the use of variables in the first-differences is related to this methodology requires that all variables be I(0) that is stationary (see Table 4); x_{it} is the vector of exogenous covariates, and ε_{it}, are the vectors of the dependent variables in a panel of fixed effects and idiosyncratic errors. The matrices $e_1, e_2, \ldots, e_{p-1}, e_p$ and matrix b are parameters to be estimated. After the PVAR regression, it is necessary to apply the specification tests to verify the characteristics of the model. To this end, the Granger causality Wald test developed by ABRIGO and LOVE (2015) will be applied. This test shows the robustness and the causality between the variables in the model.

This section showed the variables that will be used and the method that include the ARDL and PVAR models, the preliminary and specification tests. In the subsequent section will show the empirical results that include the results of preliminary and specification tests, estimation results of models I, II, III, and IV, short-run impacts, elasticities, adjustment speed, and discussions.

4. Empirical results

This section evidences the empirical results. Thus, with the purpose of the show the statistics of variables, the descriptive statistics were computed, and to verify the presence of cross-section dependence in the model, the CSD-test was applied. Table 2 shows the descriptive statistics of all variables in the natural logarithms and first-differences and the outcomes of CSD-test.

Table 2. Descriptive statistics and CSD-test

Variables	Descriptive Statistics					CSD-test			
	Obs.	Mean	Std.-Dev.	Min.	Max.	CSD-test		Corr	Abs (corr)
$LnCO_2$	430	0.5158	0.5793	-1.0094	1.5614	19.61	***	0.444	0.479
LnDOMS	426	3.7233	0.5273	1.7433	5.5170	5.56	***	0.126	0.269
LnEXP	430	23.2474	1.5631	19.8388	26.6317	40.63	***	0.922	0.922
LnFOSSIL	430	3.2145	1.0672	-2.0540	4.5407	5.12	***	0.115	0.357
LnGDP	430	8.4680	0.6572	6.9692	9.5854	26.66	***	0.605	0.704
LnGLOBAL	430	3.9505	0.1819	3.5707	4.3283	40.68	***	0.931	0.931
LnNATU_RENTS	430	1.0368	0.9884	-2.1657	3.0652	18.08	***	0.412	0.502
LnREN	422	0.5687	1.2457	-1.7500	3.7230	16.14	***	0.370	0.482
$DLnCO_2$	430	0.0112	0.0899	-0.4597	0.5231	2.82	***	0.066	0.138
DLnDOMS	423	0.0125	0.2326	-1.1685	1.5933	3.02	***	0.070	0.134
DLnEXP	430	0.0560	0.0890	-0.5208	0.3778	5.02	***	0.115	0.163
DLnFOSSIL	430	0.0027	0.4738	-3.4722	4.9671	0.18		0.003	0.166
DLnGDP	430	0.0148	0.0457	-0.3372	0.1067	12.09	***	0.280	0.289
DLnGLOBAL	430	0.0090	0.0361	-0.5431	0.0915	3.38	***	0.078	0.132
DLnNATU_RENTS	430	0.0359	0.3826	-1.4338	2.0342	15.55	***	0.361	0.383
DLnREN	421	0.0516	0.3126	-0.7692	3.6415	1.89	**	0.044	0.121

Notes: "Ln" and "D" denote variables in the natural logarithms and the first-differences of logarithms; Obs denotes the number of observations in the model; Std.-Dev. Denotes the Standard Deviation; Min. and Max. denote Minimum and

Maximum, respectively; the command *sum* of Stata was used for descriptive statistics; the command *xtcd* of Stata was used for CSD-test; *** and ** denotes statistically significant at 1% and 5% levels, respectively.

The results of CSD-test indicate the existence of cross-section dependence in all variables in the natural logarithms and first-differences, except to the variable "DLnFOSSIL". However, the presence of cross-section dependence in the variables means that the countries of the study share the same characteristics and shocks (KOENGKAN, 2018). To confirm the presence of multicollinearity between the variables, the VIF-test was computed. Table 3 shows the results of VIF-test.

Table 3. VIF-test

Variables	VIF	1/VIF	Mean VIF
$LnCO_2$	n.a.	n.a.	
LnDOMS	1.21	0.8259	
LnEXP	2.92	0.3425	
LnFOSSIL	1.24	0.8068	
LnGDP	3.32	0.3015	1.86<10
LnGLOBAL	1.54	0.6472	
LnNATU_RENTS	1.39	0.7198	
LnREN	1.39	0.7207	
$DLnCO_2$	n.a.	n.a.	
DLnDOMS	1.04	0.9625	
DLnEXP	1.07	0.9327	
DLnFOSSIL	1.04	0.9619	
DLnGDP	1.09	0.9177	1.05< 10
DLnGLOBAL	1.01	0.9692	
DLnNATU_RENTS	1.05	0.9556	
DLnREN	1.03	0.9901	

Notes: "Ln" and "D" denote variables in the natural logarithms and the first-differences of logarithms; the command *xtcd* of Stata was used; n.a. denotes "not available".

The results of Mean VIFs indicate that the variables in the natural logarithms, the multicollinearity was 1.86, while in the first-differences was 1.05, both the results are below than the benchmark of 10 established for VIF-test. Actually, in the presence of cross-section dependence and low-multicollinearity, the econometric literature recommends examining the stationarity of variables with the intention of the evidence whether the variables are I(1) or I(0) (KOENGKAN, 2018). The second-generation panel unit root tests (PESARAN, 2007) was applied. The null hypothesis of this test is that the variables are I(1) that is stationary. Table 4 shows the outcomes of the unit root test of the second generation (PESARAN, 2007).

Table 4. Unit root test

Variables	2nd Generation unit root test	
	Pesaran (2007) Panel Unit Root test (CIPS) (Zt-bar)	
	Without trend	With trend
	Zt-bar	Zt-bar
$LnCO_2$	-1.692 **	-1.063
LnDOMS	-0.639	-0.297

LnEXP	0.548		2.155	
LnFOSSIL	-1.349	*	-2.589	***
LnGDP	-1.654	**	-3.071	***
LnGLOBAL	-3.371	***	-2.095	**
LnNATU_RENTS	-2.226	***	-3.881	***
LnREN	0.767		2.812	
DLnCO_2	-10.640	***	-9.861	***
DLnDOMS	-9.540	***	-8.158	***
DLnEXP	-9.579	***	-9.926	***
DLnFOSSIL	-11.111	***	-10.584	***
DLnGDP	-6.634	***	-5.185	***
DLnGLOBAL	-11.014	***	-10.063	***
DLnNATU_RENTS	-10.513	***	-9.574	***
DLnREN	-9.678	***	-9.397	***

Notes: "Ln" and "D" denote variables in the natural logarithms and the first-differences of logarithms; null for Pesaran test: series is I(1); the lag length (1) and trend were used in this test; the command *multipurt* of Stata was used; ***, **, and * denote statistically significant at 1%, 5%, and 10% levels, respectively.

The CIPS-test was used with lag length (1) without trend and with the trend. The results of this test suggest that the variables in the natural logarithms and first differences are I(1) that is stationary. Consequently, after the realisation of preliminary tests, it is necessary to apply the specification tests to check the characteristics of the ARDL model. The specification tests were performed with the purpose of check the existence of cross-section dependence, serial correlation in the panel-data models, and groupwise heteroskedasticity in the fixed effects model (see Table 5).

Table 5. Specification tests

Tests	Statistics results by model			
	Model I (Energy – GDP)	Model II (Energy – Globalization)	Model III (GDP – Energy)	Model IV (Globalization –Energy)
Friedman test	77.320***	98.670***	56.794***	43.498***
Wooldridge's test	F(1,9)=144.135***	F(1,9)=52.256***	F(1,9)=25.968***	F(1, 9)=27.293***
Modified Wald test	x_{10}^2=152.44***	x_{10}^2=33.78***	x_{10}^2=1307.49***	x_{10}^2=862.56***

Notes: *** denotes statistically significant at 1% levels; results for H_0 of Modified Wald test: sigma(i)^2 = sigma^2 for all I; results for H_0 of Friedman test: residuals are not correlated; results for H_0 of Wooldridge test: no first-order autocorrelation.

The results of the specification tests point to the presence of cross-section dependence, serial correlation in the panel-data model, and the existence of heteroskedasticity in the models. Besides, the Breush and Pagan Lagrangian Multiplier test cannot be carried, due to the correlation matrix of residuals is singular. In the presence of cross-section dependence, the serial correlation, and the heteroskedasticity, it is recommended to use the Driscoll and Kraay (DK) estimator (e.g., FUINHAS et al., 2017; KOENGKAN, 2018; KOENGKAN et al., 2019). Indeed, this estimator can generate robust standard errors for several phenomena in the sample errors (KOENGKAN and FUINHAS,2020b; KOENGKAN, 2018). The FE-D.K. (Driscoll and Kraay) was choice as estimator due to their high significance if compared with FE and FE (Robust) estimators. Table 6 shows the estimation results of the model I and II.

Table 6. Estimation results of the ARDL model

Independent variables	FE-D.K.	
	Model I	Model II
	Dependent variable DLnGDP	Dependent variable DLnGLOBAL
Constant	-0.6780 ***	1.4045 ***
Trend	-0.0023 ***	0.0050 ***
$DLnCO_2$	0.2335 ***	n.a.
DLnDOMS	-0.0388 ***	n.a.
DLnEXP	0.0893 ***	n.a.
DLnGLOBAL	0.1298 **	n.a.
DLnNATU_RENTS	-0.0114 **	0.0095 **
$LnCO_2$	n.a.	0.0184 **
LnEXP	0.0241 ***	n.a.
LnFOSSIL	0.0093 ***	n.a.
LnGDP	-0.0506 ***	n.a.
LnGLOBAL	0.1451 ***	-0.3836 ***
LnREN	0.0047 *	-0.0065 ***
	Statistics	
N	415	422
F	13.9629	1.5328

Notes: ***, **, and * denote statistically significant at 1%, 5%, and 10% level, respectively; the Stata command *xtscc* was used; "Ln" and "D" denote variables in the natural logarithms and the first-differences; n.a. denotes "not available".

Table 6, shows the FE-D.K. estimator on the ARDL model. This estimator was performed first in the ARDL model. Additionally, the estimation results of the model I and II are statically significant (see Table 6). In view of the results of Table 6, the short-run impacts and elasticities (long-run) in the ARDL model are presented in Table 7, below.

Table 7. Short-run impacts, elasticities and adjustment speed of the ARDL model

Independent variables	FE-D.K.	
	Model I	Model II
	Dependent variable DLnGDP	Dependent variable DLnGLOBAL
Constant	-0.6780 ***	1.4045 ***
Trend	-0.0023 ***	0.0050 ***
	Short-run impacts	
$DLnCO_2$	0.2335 ***	n.a.
DLnDOMS	-0.0388 ***	n.a.
DLnEXP	0.0893 ***	n.a.
DLnGLOBAL	0.1298 **	n.a.
DLnNATU_RENTS	-0.0114 **	0.0095 ***
ECM	-0.0506 ***	-0.3836 ***
	Elasticities (Long-run)	
$LnCO_2$ (-1)	n.a	0.0481 **
LnEXP (-1)	0.4760 ***	n.a.
LnFOSSIL (-1)	0.1835 **	n.a.
LnGLOBAL (-1)	2.8671 ***	n.a.
LnREN (-1)	0.0938 *	-0.0171 ***

Notes: ***, **, and * denote statistically significant at 1%, 5%, and 10% level, respectively; the Stata command *xtscc* was used; "Ln" and "D" denote variables in the natural logarithms and the first-differences;

n.a. denotes "not available".

The short-run impacts were not observed directly on estimates, while the long-run (elasticities) in the model I and II, were computed by dividing the coefficients of the independent variables by the coefficient of dependent variables "LnGDP" and "LnGLOBAL", both lagged once, and multiplying by the ratio by (-1). So, as expected, the consumption of renewable energy and fossil sources in the long-run exerts a positive impact on economic growth (see the model I). Additionally, in model II, the consumption of renewable energy in the long-run has a negative impact on the globalisation process. The impact of variables in the short-and long-run is statistically significant at 1% level. After making the models I and II that approach the impact of consumption of energy on economic growth and globalisation, it is made the models III and IV that approach the impact of economic growth and globalisation on the consumption of energy. These models were created to understand the nexus between the variables. Table 8, evidence the results of the estimation of models III and IV.

Table 8. Estimation results of the ARDL model

Independent variables	FE-D.K.	
	Model III	Model IV
	Dependent variable DLnREN	Dependent variable DLnREN
Constant	-1.8026 ***	-1.1846 ***
DLnFOSSIL	0.0941 ***	0.0944 ***
DLnDOMS	n.a	0.1241 *
LnREN	-0.0649 ***	-0.0682 ***
LnGDP	0.2232 ***	n.a.
LnGLOBAL	n.a	0.3222 ***
	Statistics	
N	421	414
F	3.1058	4.7484

Notes: *** and * denote statistically significant at 1% and 10 % level, respectively; the Stata command *xtscc* was used; "Ln" and "D" denote variables in the natural logarithms and the first-differences; n.a. denotes "not available".

Table 8 shows the FE-D.K. estimator on the ARDL model. The estimation results of the models III and IV are statically significant (see Table 8). So, the variable "DLnFOSSIL" was not used as the dependent variable because the economic growth and globalisation do not exert any impact on this variable. After the estimation results of models III and IV, it is necessary to calculate the short-run impacts and elasticities. Table 9 shows the results of short-run impacts and elasticities in the ARDL model.

Table 9. Short-run impacts, elasticities and adjustment speed of the ARDL model

Independent variables	FE-D.K.	
	Model III	Model IV
	Dependent variable DLnREN	Dependent variable DLnREN
Constant	-1.8026 ***	-1.1846 ***
	Short-run impacts	
DLnFOSSIL	0.0941 ***	0.0944 ***

DLnDOMS	n.a.	0.1241 *
ECM	-0.0649 ***	-0.0682 ***
	Elasticities (Long-run)	
LnGDP (-1)	3.4397 ***	n.a.
LnGLOBAL (-1)	n.a.	4.7267 ***

Notes: *** and * denote statistically significant at 1% and 10% level, respectively; the Stata command *xtscc* was used; "Ln" and "D" denote variables in the natural logarithms and the first-differences; n.a. denotes "not available".

The long-run (elasticities) in the model's III and IV, were computed by dividing the coefficients of the independent variables by the coefficient of dependent variable "LnREN" lagged once and multiplying by the ratio by (-1). The results of short-run impacts and elasticities point that in the model III the consumption of fossil fuels has a positive impact on consumption of renewable energy in the short-run, and the economic growth has in the long-run. In model IV, the globalisation process has a positive impact on the consumption of renewable energy. In the next section will show the robustness of the model with the realisation of Granger causality Wald test.

5. Robustness check

To check the robustness of models, the Granger causality Wald test developed by ABRIGO and LOVE (2015) was used to identify the causality between the variables. Indeed, only the variables DLnREN, DLnFOSSIL, DLnGDP, and DLnGLOBAL, were utilised. Table 10 shows the results of the Granger causality Wald test.

Table 10. Granger causality Wald test.

Equation \ Excluded		Chi2	Df.	Prob > Chi2
DLnREN	DLnFOSSIL	45.276	1	0.000
	DLnGDP	7.211	1	0.007
	DLnGLOBAL	173.106	1	0.000
	All	209.871	3	0.000
DLnFOSSIL	DLnREN	27.696	1	0.000
	DLnGDP	130.381	1	0.000
	DLGLOBAL	196.157	1	0.000
	All	272.557	3	0.000
DLnGDP	DLnREN	2.806	1	0.094
	DLnFOSSIL	74.163	1	0000
	DLnGLOBAL	189.139	1	0.000
	All	258.951	3	0.000
DLnGLOBAL	DLnREN	11.462	1	0.001
	DLnFOSSIL	0.528	1	0.467
	DLnGDP	27.506	1	0.000
	All	56.029	3	0.000

Notes: *** and * denote statistical significance level of 1%, and 10% level, respectively; the Stata command *pvargranger* was used. Instruments: l (1/12).

The results indicate the existence of a bidirectional relationship between consumption of renewable energy and consumption of fossil fuels, economic growth and consumption of renewable energy, economic growth, and consumption of fossil fuels globalisation and consumption of renewable energy — moreover, unidirectional causality between globalisation to the consumption of fossil fuels. Fig. 1 summarises the statistically significant Granger causalities.

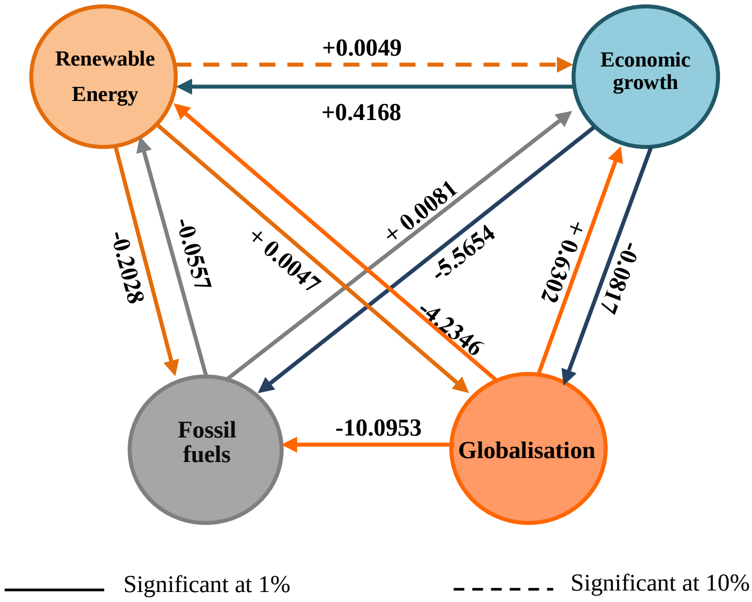

Fig.1 Granger causality

The next section will present a discussion of results and the possible explanations of the impacts in Latin America & the Caribbean region.

6. Discussions

The preliminary tests that verify the characteristics of variables evidence to the presence of cross-section dependence, low-multicollinearity, and unit-roots (see Tables 2, 3, and 4). These outcomes are in line with some investigations that approached the Latin America region (e.g., KOENGKAN, 2018; FUINHAS et al., 2017; KOENGKAN, 2017a; KOENGKAN, 2017b). Moreover, the results of specification tests point to the presence of cross-section dependence, serial correlation in the panel-data model, and also the existence of heteroskedasticity in the models I, II, III, and IV. The results of specification tests are statistically significant at 1%, and these results agree with some investigators (e.g., KOENGKAN, 2018; FUINHAS et al., 2017; KOENGKAN, 2017a; KOENGKAN, 2017b).

The results of short-run impacts, elasticities (long-run) of ARDL model in the models I, II, III, and IV are statically significant at 1% in the FE-D.K. estimator. Thus, the statically significance of variables means that they have high explanatory power. The results of the model I evidence that the consumption of renewable energy has a positive impact of 0.0938 on economic growth and the consumption of fossil has an impact of 0.1835, both the impacts in the long-run. Moreover, in the model III, the outcomes point that the economic growth exerts a positive impact of 0.2232 on the consumption of renewable energy in the long-run, while in the consumption of fossil fuels was not identified any impact. So, the results of models I and III suggests to the presence of a bidirectional relationship between consumption of renewable energy and economic growth, and the presence of unidirectional causality from consumption of fossil to economic growth (see Tables 7 and 9).

Considering this, the presence of a bidirectional relationship between consumption of renewable energy and economic growth is in line with several authors that studied this nexus (e.g., APERGIS and PAYNE, 2010; APERGIS et al., 2010; TUGCU et al., 2012; SEBRI and BEN-SALHA, 2014; KOENGKAN, 2017c; KOENGKAN, 2017d; MENEGAKI et al., 2017). According to KOENGKAN (2017e), the bidirectional relationship between economic growth and consumption of renewable energy is due to the countries of Latin America and the Caribbean region are very sensitive to changes in the economic activity, where a faster economic growth exerts a positive impact on energy use. The same author complements yet that the enormous abundance of renewable sources in the Latin America and the Caribbean region stimulate the investments in the renewable energy technologies and consequently causes a positive impact on economic growth and subsequently in the consumption of energy (KOENGKAN, 2017c). Moreover, the unidirectional causality from consumption of fossil to economic growth in the Latin American countries agrees with some authors (e.g., ACARAVCI and OZTURK, 2010; FUINHAS and MARQUES, 2011; KAIS and MBAREK, 2017; DESTEK and ASLAN, 2017; KOENGKAN, 2017d; FUINHAS et al., 2017; KOENGKAN and FUINHAS,2020a). As stated by KOENGKAN (2017d) that investigated the South American countries, the existence of unidirectional causality in the Latin American countries is due to the region's dependence on the consumption of energy to growth, where the increase of 1% in the energy use increases the economic growth in 0.5% respectively. This idea is accepted by FUINHAS et al. (2017) that confirms that the Latin American countries have a high economic dependence on fossil fuels, where some countries of this region are major fossil fuel energy producers, and others are significant importers. Other researchers, such as OMRI et al. (2014) explains that this unidirectionality between the variables is caused by the development of infrastructure, trade openness, and also economic capitalisation in the Latin American countries. These factors are responsible for the increase of consumption of fossil fuels and consequently in economic growth.

Moreover, the outcomes of models II and IV indicate that the consumption of renewable energy has a negative impact of -0.0171 on globalization process, and the globalization exerts a positive impact of 4.7267 on the consumption of renewable energy, both impacts in the long-run, while in the consumption of fossil fuels was not identified any impact between the variables (see Tables 7 and 9). The results of models II and IV suggests the existence of a bidirectional relationship between globalisation and consumption of renewable energy. In the literature, this relationship was found by several authors (e.g., KOENGKAN, 2017a; SHAHBAZ et al., 2017; YAZDI and SHAKOURI, 2017). According to KOENGKAN (2017a), the globalisation exerts a positive effect on total factor productivity and economic growth and consequently increase the energy demand. SHAHBAZ et al. (2017) have the same vision that the globalisation has a positive impact on economic growth and subsequently on energy consumption. Another explanation for this bidirectionality is that the globalisation encourages investments in renewable sources. These new investments exert a positive impact on economic growth and subsequently in energy consumption. Moreover, the globalisation can allow households and firms to purchase renewable energy technology more cheaply, increasing the consumption of green energy.

The ECM parameter of ARDL model in the models I, II, III, and IV are statistically significant at 1% (e.g., Model I (-0.0506***); Model II (-0.3836***); Model III (-0.0649***); Model IV (-0.0682***). Then, when an ECM parameter is statically significant, it is identical to the realisation of the Granger causality test (FUINHAS et al., 2017; KOENGKAN, 2018). The ECM version of Granger causality and cointegration can ensure that both magnitudes of effects and causality are revealed by the elasticity of themselves (see Tables 7 and 9).

Finally, the results of Granger causality Wald test that is the robustness check indicates the presence of a bidirectional relationship between consumption of renewable energy and consumption of fossil fuels, economic growth, and consumption of renewable energy, economic growth, and consumption of fossil fuels, globalisation, and consumption of renewable energy. A unidirectional causality between globalisation to the consumption of fossil fuels. Moreover, the Granger causality Wald test confirmed the results of ARDL models, except the bidirectional relationship between economic growth and consumption of fossil fuels and unidirectionality between globalisation to the consumption of fossil fuels. This result is due to that the PVAR models can better capture the relationships between the variables than the ARDL models. The next section will show conclusions and policy implications.

7. Conclusions and policy implications

The nexus between energy consumption and economic growth was analysed in this article. This study is focused on ten Latin American and Caribbean countries over the period from 1971 to 2014. So, the ARDL model in the form of UECM was computed. The results of preliminary tests proved the presence of cross-section dependence, low-multicollinearity, and unit-roots. Moreover, the specification tests point to the presence of cross-section dependence, serial correlation in the panel-data model, and the existence of heteroskedasticity in the models I, II, III, and IV.

The results of the ARDL model pointed out that there is a bidirectional relationship between economic growth and consumption of renewable energy and unidirectional relationship from consumption of fossil to economic growth. Then, based on these results we cannot reject the Feedback Hypothesis (4) for renewable energy and economic growth, and the Growth Hypothesis (3) for the consumption of fossil and economic growth in the Latin American & the Caribbean countries. Moreover, we cannot reject the Feedback Hypothesis (7) consumption of energy and globalisation. The results of ARDL proved too that there is a bidirectional relationship between the consumption of renewable energy and globalisation.

The results of this investigation pointed out that although the consumption of renewable energy has grown in the last thirty years, Latin American and the Caribbean countries are still dependent on fossil fuels. This dependence can be seen, if we compare the impacts of consumption of renewable energy and fossil on economic growth, where fossil fuels have a more significant impact than renewable sources in the economy. Indeed, this dependence on fossil fuels increases environmental degradation in the long-run. Another interesting result is the existence of substitutability among consumption of renewable energy and consumption of fossil fuels in periods of drought in reservoirs, where the renewable energy plants are substituted by thermoelectric plants that are powered by fossil fuel sources. This evidence can be seen if we look at the positive impact of fossil fuels on the consumption of renewable. So, this substitutability between renewable and fossil, reveals the existence of low energy diversification in Latin American and the Caribbean countries and also confirms the dependence on fossil fuels.

So, based on these results, it is necessary to create new renewable energy policies, develop conservation policies that do not retard economic growth. Moreover, encourage the domestic financial institutions in the Latin America and the Caribbean countries to give special loan discounts to business firms that have interest in investing or developing renewable technologies or purchase green technologies, and also households to purchase equipment with green technologies. So, these policies and changes are capable of an increase in the consumption of renewable energy and economic activity, and also reduce the dependence on fossil fuels and environmental degradation in Latin American & the Caribbean countries. That these results help the local governments develop new policies with the purpose of increases the consumption of renewable energy and reduces environmental degradation at the same time that promotes development.

References

ACARAVCI A.; OZTURK I. On the relationship between energy consumption, CO2 emissions and economic growth in Europe. **Energy**, v. 35, n.12, p.5412-5420, 2010.

ANG J.B. (2007) CO2 emissions, energy consumption, and output in France. **Energy Policy**, v. 35, n. 10, p.4772-4778, 2007.

APERGIS N.; PAYNE J.E.; MENYAH K.;WOLDE-RUFAEL Y.On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. **Ecological Economics**, v. 69, n. 11, p. 2255-2260,2010.

APERGIS N.;PAYNE J.E. Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. **Energy Policy**, v. 38, n. 1., p.656-660,2010.

BALZA L.H.; ESPINASA R. ; SEREBRISKY T. Lights on?: Energy Needs in Latin America and the Caribbean to 2040. **Inter-American Development Bank**, p.1-39, 2016.

BREUSCH T.S.; PAGAN A.R. The Lagrange multiplier test and its applications to model specification in econometrics. **The Review of Economic Studies**, v.47, n.1. p.239-253,1980.

CARAIANI C.; LANGU C.I.; DASCALU C. Energy consumption and GDP causality: A three-step analysis for emerging European countries. **Renewable and Sustainable Energy Reviews**, v. 44, p. 198-210,2015.

DESTEK M.A.; ASLAN A. Renewable and non-renewable energy consumption and economic growth in emerging economies: Evidence from bootstrap panel causality. **Renewable Energy**, v.111, p.757-763,2017.

FRIEDMAN M. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. **Journal of the American Statistical Association**, v.32, p. 675-701, 1937.

FUINHAS J.A.; MARQUES A.C. An ARDL Approach to the Oil and Growth Nexus: Portuguese Evidence. **Energy Sources, Part B: Economics, Planning, and Policy**, v. 7, n.3, p.282-291,2011.

FUINHAS J.A.; MARQUES A.C.; KOENGKAN M. Are renewable energy policies upsetting carbon dioxide emissions? The case of Latin America countries. **Environmental Science and Pollution Research**, v. 24, n.17, p.15044–15054,2017.

GREENE W.Econometric Analysis. **Upper Saddle River**, New Jersey: Prentice—Hall,2002.

HAGGARD S.; KAUFMAN R. Development, democracy, and welfare state: Latin America, East Asia, and Eastern Europe. **Princeton: Princeton University Press**, 2008.

HATZIGEORGIOU E.; POLATIDIS H.; HARALAMBOPOULOS D.CO2 emissions, GDP, and energy intensity: a multivariate cointegration and causality analysis for Greece, 1977-2007. **Applied Energy**, v., 88, n.4, p.1377-1385,2011.

KAIS S.; MBAREK M.B.Dynamic relationship between CO2 emissions, energy consumption and economic growth in three North African countries. **International Journal of Sustainable Energy**, v. 36, n.9, p.840-854, 2017.

KOENGKAN M. Is the globalization influencing the primary energy consumption? The case of Latin America and the Caribbean countries. **Cadernos UniFOA**, Volta Redonda, v. 12, n.33, p.59-69, 2017a.

KOENGKAN M. The nexus between consumption of biofuels and economic growth: An empirical evidence from Brazil. **Cadernos UniFOA**, Volta Redonda, v.12, n.35, p.87-98, 2017c.

KOENGKAN M.O nexo entre o consumo de energia primária e o crescimento econômico nos países da América do Sul: Uma análise de longo prazo. **Cadernos UniFOA**, Volta Redonda, v.12, n.34, p.56-66, 2017b.

KOENGKAN M.The decline of environmental degradation by renewable energy consumption in the MERCOSUR countries: an approach with ARDL modeling**. Environment Systems and Decisions**, p.1-11,2018.

KOENGKAN M.The hydroelectricity consumption and economic growth nexus: A long time span analysis. **Revista Brasileira de Energias Renováveis**, v.6, n.4, p.678-704,2017d.

KOENGKAN M.The nexus between energy consumption, economic growth, and urbanization in Latin American and Caribbean countries: An approach with PVAR model. **Revista Valore**, v.6, n.2, p.202-218,2017e.

KOENGKAN M.; FUINHAS J.A. The interactions between renewable energy consumption and economic growth in the Mercosur countries. **International Journal of Sustainable Energy**, v.39, n.6, p. 594-614, 2020a.

KOENGKAN M.; FUINHAS, J.A. Exploring the effect of the renewable energy transition on CO2 emissions of Latin American & Caribbean countries. **International Journal of Sustainable Energy**, v.39, n.6, p. 515-538, 2020b.

KOENGKAN M.; SANTIAGO R.; FUINHAS J.A; MARQUES A.C. Does financial openness cause the intensification of environmental degradation? New evidence from Latin American & Caribbean countries. **Environmental Economics and Policy Studies** , v.21, p.507–532, 2019.

KOF (Globalization index) Available in: <https://www.kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.html>. Accessed in June 06, 2020.

LEE C.C. The causality relationship between energy consumption and GDP in G-11 countries revisited. **Energy Policy**, v.34, n.9, p.1086-1093,2006.

MENEGAKI A.N. Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis**. Energy Economics**, v.33, n.2, p.257-263,2011.

MENEGAKI A.N.; MARQUES A.C.; FUINHAS J.A. Redefining the energy-growth nexus with an index for sustainable economic welfare in Europe. **Energy**, v.141, p.1254-1268,2017.

MENEGAKI A.N.; OZTURK I. Growth and energy nexus in Europe revisited: Evidence from a fixed effects political economy model. **Energy Policy**, v.61, p.881-887,2013.

NARAYAN P.K.; POPP S.The energy consumption-real GDP nexus revisited: Empirical evidence from 93 countries. **Economic Modelling**, v.29, n.2, p.303-308,2012.

OMRI A.; NGUYEN D.K.; RAULT C. Causal interactions between CO2 emissions, FDI, and economic growth: Evidence from dynamic simultaneous-equation models. **Economic Modelling**, v.42, p.382-389,2014.

PESARAN M.H.; SHIN Y.; SMITH R.J. Bounds testing approaches to the analysis of level relationships. **Journal Applied Econometrics**, v.16, n.3, p.289-326,2001.

PESARAN M.H. A simple panel unit root test in the presence of cross-section dependence. **Journal of Applied Econometrics**, v.22, n.2, p.256–312,2007.

PESARAN M.H. General diagnostic tests for cross section dependence in panels. The University of Cambridge, Faculty of Economics. **Cambridge Working Papers in Economics**, n. 0435, 2004.

PINTO A.;LAHERA E. Trade liberalization in the Latin America. **CEPAL** nº 50, p.41-62,1993.

RAHMAN S.M.; MIAH M.D. The impact of sources of energy production on globalization: Evidence from panel data analysis. **Renewable and Sustainable Energy Reviews**, v.74, p.110-115,2017.

ROJAS E.J.G. Nación y nacionalismo en America Latina. Bogota, Colombia: **Universidad Nacional de Colombia**, Centro de Estudios Sociale, ps, p.1-276,2007.

SEBRI M.; BEN-SALHA O. On the causal dynamics between economic growth, renewable energy consumption, CO_2 emissions, and trade openness: Fresh evidence from BRICS countries. **Renewable and Sustainable Energy Reviews**, v.39, p.14-23,2014.

SHAHBAZ M.; LAHIANI A.; ABOSEDRA S.; HAMMOUDEH S. The Role of Globalization in Energy Consumption: A Quantile Cointegrating Regression Approach. **MPRA** Paper No. 84682, p.1-36,2013.

SHAHBAZ M.; SHAHBAZ S.J.H.; MAHALIK M.K.; SADORSKY P. How strong is the causal relationship between globalization and energy consumption in developed economies? A country-specific time-series and panel analysis. **Applied Economics Journal**, v.50, n.13, p.1479-1494,2017.

SOYTAS U.; SARI R.; EWING B.T. Energy consumption, income, and carbon emissions in the United States. **Ecological Economics**, v.62, p.482–489,2007.

THEODORE, J.D.The Process of globalization in Latin America. **International Business & Economics Research Journal,** v.14, n. 1, p.193-198,2015.

TUGCU C.T.; OZTURK I.; ASLAN A. Renewable and non-renewable energy consumption and economic growth relationship revisited: Evidence from G7 countries. **Energy Economics**, v.34, n.6, p.1942-1950,2012.

WHEELER D. New Media Globalizing and Kuwaiti National Identity. **Middle East Journal**, v.54, p.:432-444,2000.

WOOLDRIDGE J.M. Econometric analysis of cross section and panel data. **The MIT Press Cambridge, Massachusetts London**, England,2002.

WORLD BANK DATA (WBD). Available in:< http://databank.worldbank.org/data/home.aspx>. Accessed in June 06, 2020.

YAZDI S.K.; SHAKOURI B. The globalization, financial development, renewable energy, and economic growth. **Energy Sources, Part B: Economics, Planning, and Policy**, v,12, n.8. p.704-714,2017.

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