EXPLORING THE INTERACTIONS BETWEEN RENEWABLE ENERGY, ECONOMIC GROWTH, AGRICULTURE AND URBANIZATION IN THE MERCOSUR TRADE-BLOC COUNTRIES

EXPLORANDO AS INTERAÇÕES ENTRE ENERGIA RENOVÁVEL, CRESCIMENTO ECONÔMICO, AGRICULTURA E URBANIZAÇÃO NOS PAÍSES DO BLOCO COMERCIAL DO MERCOSUL

EXPLORANDO LAS INTERACCIONES ENTRE LAS ENERGÍAS RENOVABLES, EL CRECIMIENTO ECONÓMICO, LA AGRICULTURA Y LA URBANIZACIÓN EN LOS PAÍSES DEL BLOQUE COMERCIAL MERCOSUR

Yormy Eliana Poveda*
yemelop@gmail.com

Matheus Koengkan*,**
matheuskoen@utad.pt

José Alberto Fuinhas***
fuinhas@uc.pt

*Federal Fluminense University, Niterói/RJ,Brazil
University of Évora, Évora, Portugal
*,**University of Trás-os-Montes and Alto Douro,Vila Real, Portugal
***University of Coimbra, Coimbra,Portugal

Abstract
The interactions between renewable energy, economic growth, agricultural sector, and urbanization were analyzed for the Mercosur trade-bloc countries over the period from 1980 to 2014. The analysis was performed recurring to panel vector autoregression to capture the rich connections (endogeneity) between the variables over a long period. The results support the existence of endogeneity between variables as well as the presence of a bi-directional causality, between consumption of renewable energy, urbanization, agriculture production, and economic growth, and unidirectional causality from urbanization to agriculture production.

Keywords: Agriculture; Econometric; Economics; Energy economics; Latin America; Renewable energy; Social science; Urbanization.

Resumo
As interações entre energia renovável, crescimento econômico, produção agrícola e urbanização foram analisadas para os países do bloco comercial do Mercosul no período de 1980 a 2014. A análise foi realizada recorrendo à auto-regressão vetorial de painel para capturar as ricas conexões (endogeneidade) entre os países por um longo período. Os resultados indicaram a existência de endogeneidade entre variáveis, bem como a presença de uma causalidade bidirecional, entre consumo de energia renovável, urbanização, produção agrícola e crescimento econômico e causalidade unidirecional da urbanização para a produção agrícola.

Palavras-chave: Agricultura; Econométria; Economia; Economia de energia; América latina; Energia renovável; Ciências Sociais; Urbanização.

Resumen
Las interacciones entre las energías renovables, el crecimiento económico, el sector agrícola y la urbanización se analizaron para los países del bloque comercial del Mercosur durante el período comprendido entre 1980 y 2014. El análisis se realizó recurriendo a la autorregresión de los paneles de vectores para capturar las ricas conexiones (endogeneidad) entre variables durante un largo período. Los resultados apoyan la existencia de endogeneidad entre variables, así como la presencia de una causalidad bidireccional, entre el consumo de energía renovable, la urbanización, la producción agrícola y el crecimiento económico, y la causalidad unidireccional de la urbanización a la producción agrícola.

Palabras llave: agricultura; Econométrico; Ciencias económicas; Economía energética; America latina; Energía renovable; Ciencias Sociales; Urbanización.

1.Introduction

The consumption of energy in the Latin America region has more than tripled between 1971-2013, where 1971 the consumption of energy was 248 million tonnes of oil equivalent (MTOE), and in 2013 it was 848 MTOE (BALZA et al., 2016). Moreover, the region is one of the regions with the most significant shares of renewable energy sources in the energy matrix. This high share is due to the hydroelectricity, biofuels, and biomass to the energy supply (FUINHAS et al., 2017). The region has experimented a rapid growth in the consumption of this kind of source, and there is apparent interest in the developing ones. This increase is related to the economic growth of these countries that had an average annual growth rate of approximately of 3.0%, where 1971 the Gross Domestic Product (GDP) *per capita* in US dollar was US$ 668.00, and in 2013 it was US$ 10,157.00 (WORLD BANK DATA, 2018).

Moreover, influenced by the growth of world population, economic of Latin American and developed and other developing countries the agriculture production in the region had an increase superior to 2.5% between 1981-2001. Indeed, the annual average rate of output growth for the entire region was 2.31% (AVILA et al., 2010). Additionally, it is expected an increase in food demand of 85% of the 690 million tons of growth in global demand for cereals between 1995 and 2020. This amount represents 10.6% of agriculture production in the Latin America region (AVILA et al., 2010).

The influence of economic growth and the increase of agriculture production that introduced the new agricultural technologies and industrialization process provoked a restructuring of rural economies of most Latin American countries. This restructuring made the urbanization grew from 25%, in the 1920s to 48.9%, in the 1960s. During the period from 1975 to 2007, the urbanization rate rose by 0.78%, and it is projected to be 0.36%, between 2007 and 2025 (KOENGKAN et al., 2018a).

In the Mercosur trade-bloc that was created in 1991 through the Asunción Treaty, with the purpose of the free trade and the fluid movement of goods and services, people, and currency among the associate countries (KOENGKAN, 2018b), it is not different. The consumption of renewable energy represents 20% of total energy consumption in 2009 (SANTOS, 2015). The investments of this kind of source grew in trade-bloc 13% between 2000 and 2013. Indeed, this increase in investments is related to receiving foreign direct investment (FDI) in the region. The bloc won 47.6% of all the FDI flow directed to Central America, South America, and Mexico in 2012. In accordance, it has made the GDP of the region reach US$ 3.32 trillion (MERCOSUR, 2018).

Moreover, in the Mercosur countries, especially in Argentina and Brazil, are considered essential actors in world agricultural production, both regarding products vegetables and animals. The trade-bloc accounts for 8% of world corn supply and provides around 40% of world soybean production. Brazil is the world’s largest producer of sugarcane, and its production has tripled since 1999. Additionally, the Mercosur produces almost 20% of world bovine meat production. The output of chicken meat is up in Brazil and presented 13% of world production in 2004 (AIS, 2007).

Finally, the region is highly urbanized, where the Mercosur trade-bloc has three global cities São Paulo, Buenos Aires, Rio de Janeiro, and Caracas. This process of urbanization in the countries of Mercosur trade-bloc make the urban population grow 30% in the 1940s, 60% in 1970s, and in 2000s 80% of the people living in cities. It means that the most important urban centres such as Buenos Aires, São Paulo, Rio de Janeiro, and Caracas had an increase of 10% of the urban population in specific periods (MARTINS, 2002).

Based on these facts, the central question of this investigation is: What is the causality between the consumption of renewable energy, economic growth, agriculture production and urbanization in the Mercosur trade-bloc countries? How do these causalities work in Mercosur countries? – With the purpose of answer these questions, the relationship between economic growth, agriculture production, consumption of non-fossil fuels, and urbanization will be investigated in five countries from Mercosur trade-bloc from 1980 to 2014. The panel vector autoregression (PVAR) model developed by HOLTZ-EAKIN et al. (1988) was applied as the method with the aim of the realization of this investigation.

This investigation is original in the literature for the following reasons that need to be highlighted (i) the inclusion of variables agriculture production, urbanization, and consumption of energy. The first studies in literature focused only on the consumption of energy, fossil fuels consumption, and primary energy consumption. Moreover, does not include in the model the variables agriculture production and urbanization to explain the economic growth and consumption of renewable energy or non-renewable; (ii) the use of PVAR model as the method. Several studies that examined this kind of the causality, only use Dynamic OLS (DOLS), Fully Modified OLS (FMOLS), Panel Autoregressive Distributed Lag (PARDL), and Granger causality test. The PVAR is a new technique and that need to employed to investigate these causalities as well as is more precise than others; (iii) the new approach using the Mercosur trade-bloc, given that this group of countries is not addressed in the literature that approaches this topic or any other. The existing researches only focused on Asia, the Middle East, and Europe countries. The Latin American region is an unexplored field that needs to deep because there is a social, political, and economic phenomenon that can explain the relationship between economic activity and consumption of energy; 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 essential for the following reasons that need to be emphasized: (i) help the policymakers to develop appropriate renewable energy policies to increase the investments and stimulates the consumption of this kind of source; (ii) it is necessary to comprehend how the variables interact in the Mercosur countries; and (iii) the results of this investigation will contribute to scarce literature that research this nexus or similar.

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

2. Literature review

The relation between energy and economic growth had been studied since the seventies. The oil crises in 1973-1974 and 1978-1979 showed the importance of energy in the production process. The pioneering study was made by KRAFT AND KRAFT (1978). They found a unidirectional causality from Gross National Product (GNP) to Energy Consumption in the United States for the 1947-1974 period. Since then, the number of studies that analysed the relationship between energy consumption and economic growth increased growly (e.g., ABOSEDRA and BAGHESTANI, 1989; AL-IRIANI, 2006; FALLAHI, 2011). The results were varying according to each country and region. Since one hand, some studies reveal that energy consumption encourages economic growth (e.g., ASAFU-ADJAYE, 2000; SOYTAS and SARI, 2003; ESEN and BAYRAK, 2017). In contrast, other studies found that there is no evidence that energy consumption is the source of GDP growth (AL-IRIANI, 2006). There are studies such as NASREEN and ANWAR (2014) about Asian countries that reveal a bi-directional causality between economic growth and energy consumption.

From the literature review, these studies have been used variables as Gross Domestic Product (GDP), capital stock, trade openness, electricity consumption, aggregated energy consumption, and energy prices. However, the incorporation of variables as renewable energy has been recently studied. The results of those studies have no consensus because it depends on the period, the methodology and other structural factors of each country.

Different economies support research on the positive effect of renewables in economic growth. BOWDEN and PAYNE (2009) tested the sectoral causal relationship between renewable and non-renewable energy consumption and economic growth in the US over the period 1949-2006. Findings revealed that there is a definite unidirectional causality from residential renewable energy consumption to real GDP. These findings are related to the presence of the growth hypothesis. Other studies are supported by TANSEL et al. (2012) show that either renewable and non-renewable energy consumption determine the economic output in G7 countries for the 1980-2009 period. They used the Autoregressive Distributed Lag approach to cointegration. PAO and FU (2013) investigate the relationship between both clean and non-clean energy consumption and economic growth in Brazil for the 1980-2009 period.

The findings of the vector correction models indicate the presence of uni-directional causality from non-hydroelectric renewable energy consumption to economic growth. BHATTACHARYA et al. (2016) suggest that renewable energy consumption has a positive impact on the economic growth for 57% of the 38 selected countries during the 1991 to 2012 period. They estimated the long-run output elasticities using panel techniques.

In contrast, OZTURK and ACARAVCI (2010) from the Granger causality model show that energy consumption per capita does not cause real GDP per capita in Turkey for 1968–2005 period. Alternatively, some authors reveal the existence of a bi-directional relationship between renewable and economic growth. OCAL and ASLA (2013) analysed that relationship in Turkey, but the results are inconsistent. Since one hand, from the ARDL approach show that renewable energy consumption hurts economic growth. Since the other hand, with the Toda-Yamamoto causality tests, exists evidence that there is a uni-directional causality running from economic growth to renewable energy consumption. It suggests the existence of the hypotheses of conservation for the relationship between renewable energy consumption and economic growth in Turkey. LIN and MOUBARAK (2014) employed a Granger causality test and found that exists bi-directional long-term causality between renewable energy consumption and economic growth for China for the period from 1977 to 2011. AL-MULALIE et al. (2014) showed that exist a bi-directional relationship between economic growth, renewable and non-renewable electricity consumption, capital, labour and trade in Latin American countries. They denote the difference between renewable and non-renewable electricity consumption and show that renewable electricity is more significant that non-renewable electricity in promoting economic growth in short- and long-run.

From the literature review is found studies about the effect of urbanization in energy consumption and economic growth. However, studies measuring that relationship are limited. In the literature, urbanization is related to increasing local returns to scale (BRÜCKNER, 2012). Despite, BRÜCKNER (2012) indicates that urbanization hurt economic growth in large African countries with high levels of ethnic polarisation, low initial per capita income, and high levels of primacy. By instrumental variables, BRÜCKNER (2012) analysed the effect that economic growth and size agricultural sector had on urbanization during the period 1960-2007. BRÜCKNER (2012) not examine the relationship between urbanization and energy and focus on the relationship between agricultural sector, urbanization, and economic growth. FRANCO et al. (2017) indicate that urbanization has a positive impact on economic growth and energy consumption but is negative on CO_2 emissions in India. BAKIRTAS and AKPOLAT (2018) analysed the relationship between energy consumption, urbanization and economic growth in New Emerging-Market Countries (Colombia, India, Indonesia, Kenya, Malaysia, and Mexico) using Dumitrescu-Hurling panel Granger causality test for the period 1971-2014. The results show that there is causality from urbanization to energy consumption and economic growth.

While some studies are examining the relationship between renewable and non-renewable energy consumption, economic growth, and urbanization, from the literature review is not detected, analyses incorporating agricultural variables together. JEBLI and YOUSSEF (2016) investigated the causal relationships between agriculture and renewable energy and evaluated their impact on CO_2 emissions for the case of Tunisia for the period from 1980 to 2011. By cointegration techniques and Granger causality tests, they indicate the existence of long-run bi-directional causality between agricultural value-added and renewable energy. It means that in the long-run, increasing renewable energy consumption has a positive effect on agricultural production. Also, increasing agricultural value-added can contribute to the production and consumption of renewable energy.

The literature showed that energy consumption is taken as a welfare indicator in both developing and developed countries. However, the results of the causality link between renewable energy consumption and economic growth are different. Was detected unidirectional from renewable energy to economic growth in the US, G7 countries and Brazil and other 38 developed and developing countries (BOWDEN and PAYNE, 2009; TUGCU et al., 2012; PAO and FU, 2013; BHATTACHARYA et al., 2016). In contrast, LIN and MOUBARAK (2014) and AL-MULALIE et al. (2014) found a bi-directional causality between renewable energy and output in China and Latin American countries, respectively. In Algeria, there is no evidence that renewable energy has a positive effect on economic growth (AMRI, 2017). From the literature review, it was identified the absence of studies with a focus on the relationship between renewable and non-renewable energy, economic growth, urbanization and agricultural variables.

3. Material and method

This section is divided into two parts. In the first one, the material that includes the database and the variables are described, and the second part illustrates the method that will be used in this investigation.

3.1. Material

To study the relationship between economic growth, consumption of renewable energy, urbanization, and agriculture production were selected five countries from Mercosur trade-bloc (i.e., Argentina, Brazil, Paraguay, Uruguay, and Venezuela (RB)). The Southern Common Market is a sub-regional bloc that was created in 1991, with the purpose of the free trade and the fluid movement of goods and services, people, and currency among the associate countries (KOENGKAN, 2018b). The period from 1980 to 2014 available for all variables was used. The reason to choose the community of Mercosur trade-bloc countries were: (i) has a rapid economic growth; (ii) has registered a rapid development and consumption of renewable energy; and (iii) has experimented a fast process of urbanization, and the economy of the Mercosur trade-bloc is based on primary activities, such as agriculture, livestock, and fisheries, where Argentina and Brazil are one of the major's agriculture producers in the world. The variables used in this investigation are described, and the sources are shown in Table 1.

Table 1. Description and sources of variables

Variables	Description	Sources

GDP	Gross Domestic Product (GDP) in constant local currency units (LCU)	World Bank Data (WBD)
RES	Renewable energy consumption (Renewable) in a Billion kilowatt-hour (kWh) from biomass, hydropower, solar, photovoltaic, wind, wave, and waste.	International Energy Administration (IEA)
URBA	Urbanization index (Urba) that refers to people living in urban areas as defined by national statistical offices.	World Bank Data (WBD)
AGRO	Food production index (2004-2006=100) Food production index covers food crops that are considered edible and that contain nutrients. Coffee and tea are excluded because, although edible, they have no nutritive value.	World Bank Data (WBD)

The variables used in this investigation were transformed in *per capita* values using the total population (from World Bank Data) of each country, except the variables URBA and AGRO. The use of *per capita* values can reduce the effects of population disparity, among the countries of the panel's data (e.g., KOENGKAN, 2018b; KOENGKAN, 2018c). Additionally, the use of GDP in constant local currency units (LCU), instead of constant US dollars, mitigate the effect of the inflation (otherwise present in the variables of the model) and the deviation of exchange rates from their fundamentals (KOENGKAN et al., 2018a). The exchange rates often deviate from their long-run fundamental equilibrium for long-time spans.

Moreover, if this investigation use variables in US dollars could exacerbate the cross-sectional dependence and add exogenous disturbance to the panel data. This cross-section dependence could compromise the estimation of the model. After the choice of variables, it is necessary to show the method that will be used in this investigation.

3.2. Method

To investigate the relationship between the variables, the PVAR model was used. This model was developed by HOLTZ-EAKIN et al. (1988) as an alternative to multivariate simultaneous equation models. Moreover, this methodology is used by macroeconomists and policymakers as an alternative to multivariate simultaneous equation model (KOENGKAN et al., 2018a). Additionally, this model was employed in empirical researches that have several applications in forme in the literature (LIU and KIM, 2018). Table 2 shows the PVAR models applications in the literature.

Table 2. PVAR model applications in the literature

Model	Applications
PVAR model	▪ Economic growth, consumption of energy, and environmental degradation (KOENGKAN et al., 2018a); ▪ Consumption of energy, financial development, economic growth (SADORSKY, 2010); ▪ Financial development and investment decisions (LOVE and ZICCHINO, 2006); ▪ Ecological Footprint, Foreign Direct Investment, and Gross Domestic Production (LIU and KIM, 2018); ▪ External shocks (e.g., natural disaster, commodity prices, and international economy) to the output of instability (RADDATZ, 2007).

According to ANTONAKAKIS et al. (2017) the PVAR models presents several advantages for their users, such as: (i) it is useful in the presence of a little theoretical information about the relationship between the variables; (ii) permits to address the endogeneity problem between the variables of the model; (iii) it can determine whether the effects of variables are in the short and long-run or both; (iv) allows to include country fixed-effects that capture the time-invariant components, and (v) lets to account any global shocks that impact all countries in the same time in the model. These advantages make this method a technique more flexible than Dynamic OLS (DOLS), Fully Modified OLS (FMOLS), and Panel Autoregressive Distributed Lag (PARDL). Indeed, all these methods cited above were tested and proved to be inefficient for the realization of this study. The following linear equation represents the PVAR model:

$$\lambda_{it} = \lambda_{it-1}e_1 + \lambda_{it-2}e_2 + \ldots + \lambda_{it-p+1}e_{p-1} + \lambda_{it-p}e_p + x_{it}b + u_{it} + \varepsilon_{it} \\ i \in \{1,2,\ldots,N\}, t \in \{1,2,\ldots T_i\} \quad (1)$$

Where λ_{it} is a $(1*k)$ vector of dependent variables; x_{it} is a $(1*k)$ vector of exogenous covariates, ε_{it}, $(1*k)$ are the vectors of the dependent variables in a panel of fixed effects and idiosyncratic errors, respectively. The matrices $e_1, e_2, \ldots, e_{p-1}, e_p$ and matrix b are parameters to be estimated. Moreover, according to ABRIGO and LOVE (2015), the PVAR model assumed that the formulations have the following characteristics:

$$A[a_{it}] = 0,\ A[a_{it}^{'}a_{it}] = \sum_{,} A[a_{it}^{'}a_{it}] = 0,\ for\,all\,t > s \quad (2)$$

Indeed, these parameters above according to ABRIGO and LOVE (2015) are capable of being an estimated jointly with the fixed effects (FE) or independently of the FE after some transformation, using an equation by Ordinary Least Squares (OLS). So, this investigation specified the second order of the PVAR model as follow:

$$Z_{it} = \Gamma_0 + \Gamma_1 Z_{it-1} + \Gamma_2 Z_{it-2} + \mu_i + e_{c,t} + \varepsilon_t \quad (3)$$

Where, Z_{it} is the vector of dependent variables that are represented by variables in the first-differences (e.g., DLnGDP, DLnRES, DLnURBA, and DLnAGRO). The used of variables in the first-differences is due to the PVAR model requires that all variables be stationary (see Table 4); Γ_1, Γ_2 are the parameters to be estimated, and ε_t is the vector of the dependent variables in a panel of fixed effects and idiosyncratic errors, respectively. The conceptual framework (Fig. 1) highlights the methodological approach that will be used in the PVAR model.

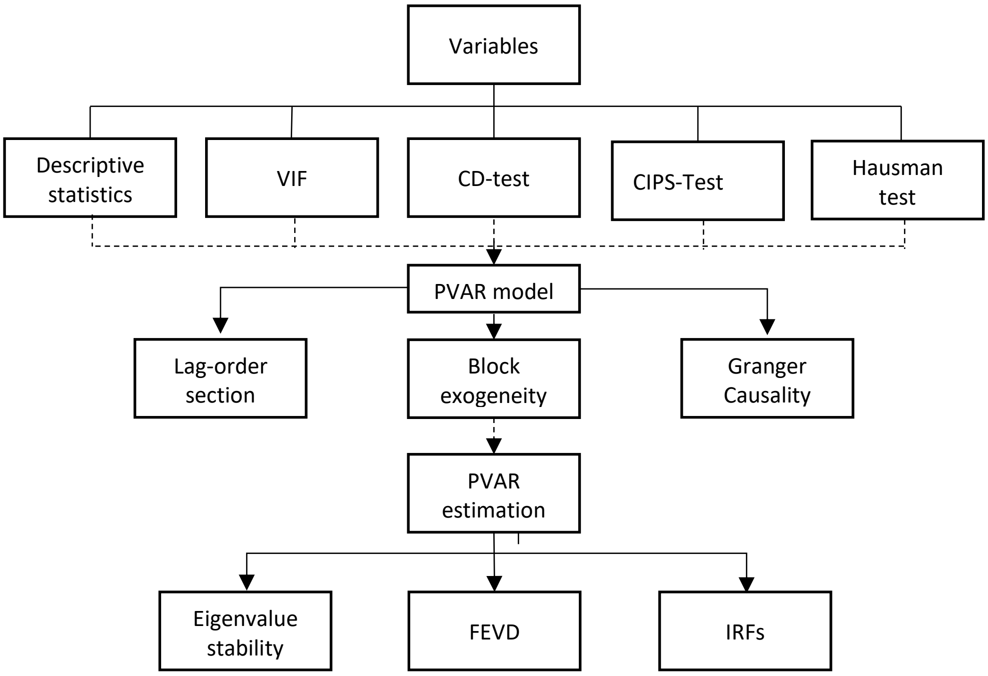


Fig.1 Conceptual framework of empirical research

So, before the realization regression, it is recommended to check the properties of variables. For this, some preliminary tests were computed, namely: (a) Variance Inflation Factor (VIF); (b) 2nd generation unit root test (CIPS-test); (c)Hausman test, and;(d) PVAR lag-order selection test. Afterwards, the regression, it is necessary to apply the specification tests to verify the proprieties of the model. To this end, some diagnostics tests developed by ABRIGO and LOVE (2015) will be computed, namely: (a) Panel Granger causality Wald test; (b) Eigenvalue stability condition test; (c) Forecast-error variance decomposition (FEVD), and; (c) Impulse-response function test. The software Stata 15.1 was utilised to perform all econometric equations of this study. In the next section will be shown the results.

4. Results

This section shows the outcomes of the descriptive statistics, preliminary tests, the PVAR regression, and specification tests. To verify the characteristics of variables, the descriptive statistics were computed. Table 3 shows the descriptive statistics of variables.

Table 3. Descriptive statistics

Variables	Descriptive Statistics					
	Obs.	Mean	Std.-Dev.	Min.	Max.	JB
LnGDP	174	10.5056	2.6257	7.2285	15.2759	2.0926
LnRES	175	-13.2067	0.8657	-15.4224	-11.4340	3.0244
LnURBA	175	16.4628	1.5066	14.0976	18.9772	1.6749
LnAGRO	175	4.3475	0.3557	3.6550	5.2362	2.3664

Notes: (Ln) denotes variables in the natural logarithms; Obs. denotes the number of observations in the model; Std.-Dev. denotes the Standard Deviation; Min. and Max. denote Minimum and Maximum; JB JarqueBera, respectively; the command *sum* of Stata was used.

The 174 observations in the variable "LnGDP" is due to the unavailability of data in 2014 for Venezuela, where the country suffered a severe financial and political crisis, and that does not make available their GDP for this year by Central Bank (KOENGKAN, 2018b). To assesses the presence of multicollinearity and the stationarity of variables. The VIF and 2[nd] generation unit root test (CIPS-test) were applied. So, the VIF-test (BELSLEY et al., 1980) with the purpose to verify the existence of multicollinearity among the variables. This test indicates the impact of multicollinearity on the estimated regression coefficients (O'BRIEN, 2007). The VIF-test can be equivalently expressed as:

$$VIF_i = \frac{1}{1 - R_J^2}, \tag{4}$$

Where R_j^2 is the coefficient of determination of regression of model in step one. Moreover, 2nd generation unit root test (CIPS-test) which includes PESARAN (2007) panel unit root test (CIPS-test) for multiple variables and lags - this test checks the presence of unit-roots - the null hypothesis of Pesaran's CIPS-test is the series is non-stationary. The following equation represents this test:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_{i,} \tag{5}$$

Where $CADF_i$ is the cross-sectionally Augmented Dickey-Fuller statistic for the $i-th$ cross-section unit given by the t-ration of b_i in the CADF regression (GENGENBACH et al., 2008). Table 4 evidence the results of VIF and CIPS-tests.

Table 4. VIF and Unit root tests

Variables	VIF-test			Pesaran (2007) Panel Unit Root test (CIPS) (Zt-bar)			
				Without trend		With trend	
	VIF	1/VIF	Mean VIF	Zt-bar	p-value	Zt-bar	p-value
DLnGDP	n.a.			-5.296	***	-4.039	***
DLnRES	1.06	0.9431		-6.440	***	-5.263	***
DLnURBA	1.05	0.9555		-2.390	***	-2.453	***
DLnAGRO	1.02	0.9848	1.04	-7.049	***	-6.366	***

Notes: *** denotes statistically significant at 1% levels; (D) denotes variables in the first-differences of logarithms; Null for CIPS tests: series is I (1); the command *multipurt* of Stata and the lag length (1) and trend were used in this test; n.a. denotes not available.

The VIF-test indicate the presence of low multicollinearity because the Mean VIF of variables in the first-differences was 1.04. This result is below than the benchmark of 10 established by VIF-test. Additionally, the results of CIPS-test show that all variables, in the first-differences, are stationary, thus ensuring that the condition of use of the PVAR panel is satisfied. The Hausman test was performed to determine whether the panel model has random (RE) or fixed effects (FE). This test has the null hypothesis that the appropriate model is RE. This test is represented by the following equation:

$$H = (\beta_{RE} - \beta_{FE})' \hat{\sum} - 1(\beta_{RE} - \beta_{FE}) \sim X^2(k) \quad (6)$$

Where β_{RE} and β_{FE} are estimators of the parameter β. The Hausman test is statistically significant (Chi2(4)=31.25, with p-value = 0.000), thus indicating the FE model as the better one. After the realization of the Hausman test, the PVAR lag-order selection was applied to report the model's overall coefficients of determination (HANSEN, 1982). So, The PVAR lag-order selection is represented by the following equation:

$$e_t = \mu + \sum_{i}^{p} \beta_{iet-1} + \varepsilon_t \tag{7}$$

with p lags of e_t to

$$\forall e_t = \delta + \gamma_t + \alpha\left(\rho^{'et-1} + \nu + \sigma_t\right) + \sum_{i}^{p-1} \Gamma_{\forall et-1} + \varepsilon_t \tag{8}$$

with $p-1$ lags of the $\forall e_t$.

So, the overall coefficient of determination (CD), Hansen´s J statistic (J), p-value (Jp-value), moment model selection criteria (MMSC)- Bayesian information criterion (MBIC), MMSC-Akaike information criterion (MAIC), and MMSC-Hannan and Quinn information criterion (MQIC) were applied. Table 5 shows the results of lag-order selection.

Table 5. PVAR lag-order selection

Lags	CD	J	Jp-value	MBIC	MAIC	MQIC
1	0.9972	110.1759	0.4237*	-410.4145	-105.8241	-229.5559
2	0.9980	81.7324	0.7695	-361.7335	-102.2676	-207.6687
3	0.9964	64.2687	0.8290	-302.0727	-87.73129	-174.8018

Notes: The Stata command *pvarsoc* was used.

The results of Hansen´s J statistic (J) is higher at one lag, and the MBIC, MAIC, and MQIC estimations are lower at one lag. After the preliminary tests, the PVAR regression was done. So, the regression of PVAR is represented by the following linear equation:

$$Z_{it} = \Gamma_0 + \Gamma_1 Z_{it-1} + \Gamma_2 Z_{it-2} + \mu_i + e_{c,t} + \varepsilon_t \tag{9}$$

Where, Z_{it} is the vector of dependent variables that are represented by variables in the first-differences (e.g., DLnGDP, DLnRES, DLnURBA, and DLnAGRO); Γ_1, Γ_2 are the parameters to be estimated, and ε_t is the vector of the dependent variables in a panel of fixed effects and idiosyncratic errors, respectively. Table 6 shows the results of the PVAR model. The lag length (1), indicate by Panel VAR lag-order selection (see Table 5) was used in the PVAR regression.

Table 6. Results of PVAR

Response of	Response to							
	$DLnGDP^{(t)}$		$DLnRES^{(t)}$		$DLnURBA^{(t)}$		$DLnAGRO^{(t)}$	
$DLnGDP_{(t-1)}$	0.2610	***	1.4047	***	0.0021	***	-0.4064	***
$DLnRES_{(t-1)}$	-0.0076	***	-0.4474	***	-0.0001	***	0.0576	***
$DLnURBA_{(t-1)}$	-0.7365	***	1.3641	***	0.9811	***	-4.332	***
$DLnAGRO_{(t-1)}$	-0.0477	***	-0.5134	***	0.0000		-0.1503	***
N. obs	124							
N. panels	5							

Notes: *** denotes statistical significance level of 1%; (D) denotes variables in the first-differences of logarithms; the Stata command *pvar* with one lag was used. Instruments: l (1/8).

The PVAR regression shows the existence of endogeneity in the panel's data. Moreover, all variables in the PVAR equation is statistically significant at 1% level. After the regression, the characteristics of the model need to be verified. To this end, the specification tests created by ABRIGO and LOVE (2015) were used. The Granger causality Wald test was used to check the causal nexus between the variables of the model. Table 7 shows the results of the Panel Granger causality Wald test.

Table 7. Panel Granger causality Wald test

Equation \ Excluded		chi2	Df.	Prob > chi2
DLnGDP	DLnRES	11.747	1	0.001
	DLnURBA	38.701	1	0.000
	DLnAGRO	41.017	1	0.000
	All	68.868	3	0.000
DLnRES	DLnGDP	356.792	1	0.000
	DLnURBA	9.869	1	0.002
	DLnAGRO	877.236	1	0.000
	All	1071.403	3	0.000

DLnURBA	DLnGDP	55.294	1	0.000
	DLnRES	11.386	1	0.001
	DLnAGRO	0.316	1	0.578
	All	178.154	3	0.000
DLnAGRO	DLnGDP	220.803	1	0.000
	DLnRES	102.101	1	0.000
	DLnURBA	396.547	1	0.000
	All	1403.419	3	0.000

Notes: D and Ln denote variables in the first-differences and the natural logarithms, respectively; the Stata command *pvargranger* was used.

The results of the Panel Granger causality Wald test point to the existence of bi-directional causality between consumption of renewable energy, urbanization, agriculture production, and economic growth, and unidirectional causality from urbanization to agriculture production. Fig. 2 summarises the statistically significant Panel Granger causalities.

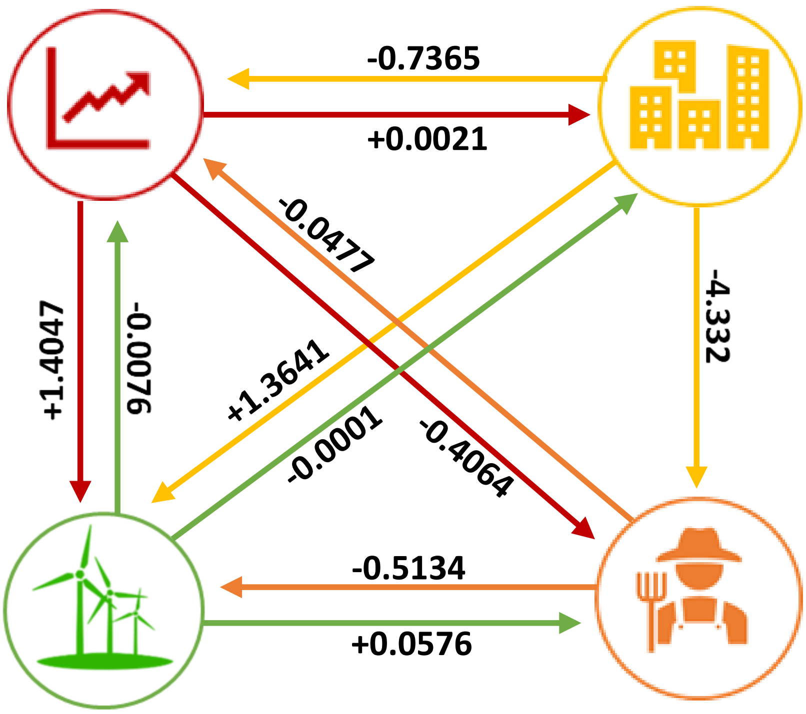
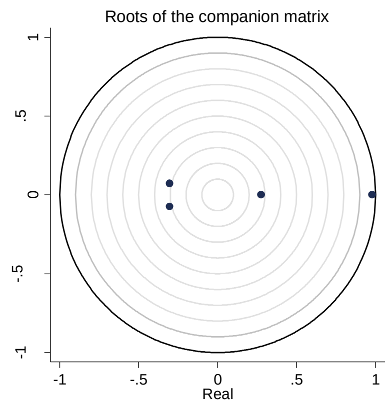


Fig 2. Granger causality

After the causality Wald test, the eigenvalue stability condition was calculated. Table 8 displays the eigenvalues and the graph of the eigenvalues, i.e., the stability condition.

Table 8. Eigenvalue stability condition

Eigenvalue			Graph
Real	Imaginary	Modulus	
0.9790	0	0.9790	
-0.3042	-0.0735	0.3130	
-0.3042	0.0735	0.3130	
0.2739	0	0.2739	

Notes: The Stata command *pvarstable* was used.

The analysis of eigenvalues reveals that the model is stable, where all eigenvalues are inside the unit circle, i.e., they satisfy the stability condition of the model. After the realization of the stability condition test, the FEVD was computed. This test is based on the Cholesky decomposition of the underlying PVAR model. In this test, the standard errors and the confidence intervals are based on the Monte Carlos simulation. So, the FEVD test is characterised by the following equation:

$$a_{it+h} - E[a_{it} + h] = \sum_{i=0}^{h-1} e_{i(t+h-i)} \varpi_i \tag{10}$$

Where a_{it-h} is the observed vector at a time $t+h$ and $E_{a[_{it+h}]}$ is the $h-$step ahead predicted vector made at the time t. Table 9 shows the outputs of FEVD.

Table 9. Forecast-error variance decomposition (FEVD)

Response variable and forecast impulse variable horizon		Impulse variable			
		DLnGDP	DLnRES	DLnURBA	DLnAGRO
DLnGDP	0	0	0	0	0
	1	1	0	0	0
	5	0.9911	0.0000	0.0004	0.0084
	10	0.9904	0.0000	0.0011	0.0084
	15	0.9899	0.0000	0.0017	0.0084
DLnRES	0	0	0	0	0
	1	0.01474	0.9853	0	0
	5	0.04566	0.8744	0.0007	0.0797
	10	0.04517	0.87424	0.0009	0.0797
	15	0.04517	0.87414	0.0010	0.0797
DLnURBA	0	0	0	0	0
	1	0.0174	5.69e-06	0.9825	0
	5	0.0595	0.0006	0.9398	9.60e-06
	10	0.0668	0.0007	0.9324	5.93e-06
	15	0.0692	0.0007	0.9300	4.72e-06
DLnAGRO	0	0	0	0	0
	1	0.2004	0.0467	0.0043	0.7484
	5	0.2357	0.0588	0.0061	0.6992

	10	0.2353	0.0587	0.0084	0.6974
	15	0.235	0.0585	0.0103	0.6960

Notes: The Stata command *pvarfevd* was used.

The FEVD-test (see Table 9) shows that one period after the shock, the variables themselves explained almost all the forecast error variance. So, fifteen periods after a shock on DLnGDP, the variable explains the forecast error variance in 99%, DLnRES explains 0.0%, DLnURBA explains 0.17%, and DLnAGRO 0.84%. The variable DLnRES fifteen periods after a shock explains the forecast error variance in 87%, while the variables DLnGDP explains 4.5%, DLnURBA 0.1%, and DLnAGRO explains 7.97%. Moreover, the variable DLnURBA fifteen periods after a shock explains the forecast error variance in 93%, while the variables DLnGDP explains 6.92%, DLnRES explains 0.7%, and DLnAGRO explains 0.0%. Finally, the variable DLnAGRO five periods after a shock explains, the forecast error variance in 70%, DLnGDP explains 24%, DLnRES 5.88%, and DLnURBA explains 0.6%. Assured the stability condition, the impulse – response functions test was computed. This test calculates the plots of impulse-response functions (IRF). The confidence bands of IRFs are estimated using Gaussian approximation and base on the Monte Carlo simulation. Fig. 3, shows the impulse – response functions.

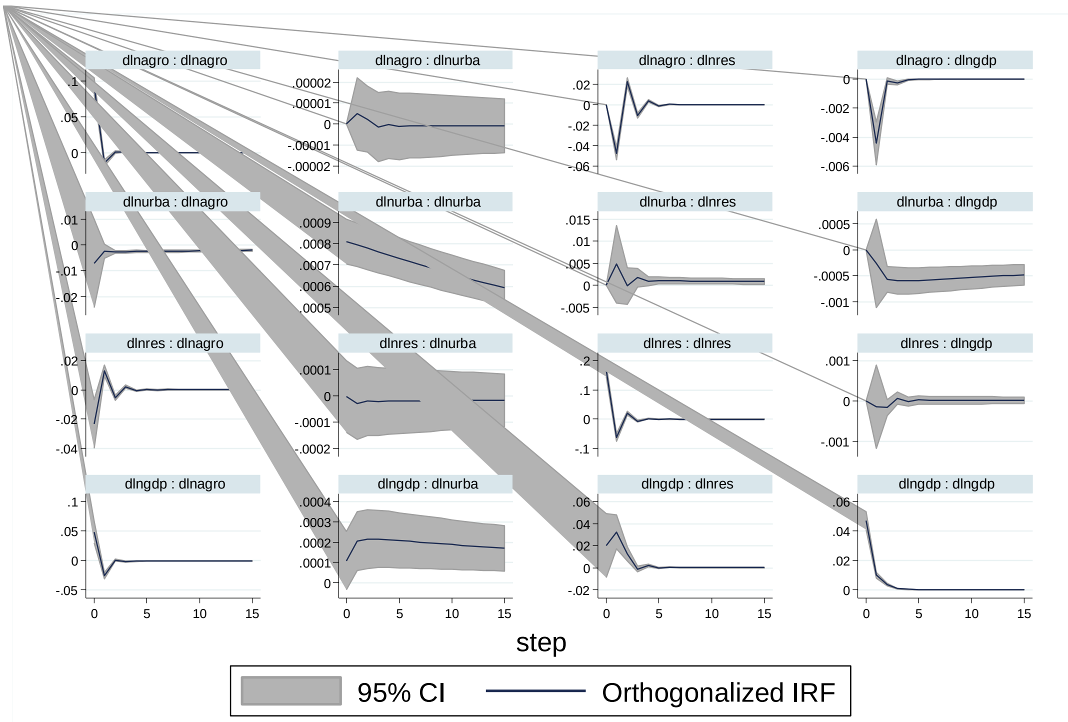


Fig.3. Impulse – response functions; the Stata command *pvarirf* was used.

In the long run, of all variables converge to equilibrium, supporting that the variables of the model are stationary. This section showed the empirical results and the next section would explain the discussions about the empirical results found.

5. Discussion

The relationship between economic growth, consumption of renewable energy, agriculture production, and urbanization was investigated. So, the preliminary tests that verify the proprieties of variables indicated the existence of low-multicollinearity, unit roots in all variables in the first-differences, the presence of fixed effects, and the need to use the lag length (1) in the PVAR model.

So, the empirical results of PVAR point that the consumption of renewable energy reduces in -0.0076 the economic activity, the urbanization -0.7365 and agriculture production -0.0477. The economic growth increases the consumption of renewable energy in 1.4047 and urbanization 1.3641, while agriculture production reduces the consumption of renewable energy in -0.5134. Moreover, the consumption of renewable energy reduces the urbanization in -0.0001, while economic activity has a positive impact of 0.0021 in the urbanization. Finally, economic growth decreases in -0.4064 agriculture production and -4.332 the urbanization, while the consumption of renewable energy increases agriculture production in 0.0576 (see Table 6).

Moreover, the results of specification tests, i.e., Granger causality Wald test indicate the existence of the bi-directional relationship, between consumption of renewable energy, urbanization, agriculture production, and economic growth, and also a unidirectional between agriculture production to urbanization. So, the Eigenvalue stability condition point that the PVAR model is stable and the Impulse-response functions that all variables of model converge to equilibrium (see Tables 8 and 9, and Figs. 2 and 3).

The bi-directional relationship between economic growth and consumption of renewable energy, evidence that the Mercosur trade-bloc countries are dependent on renewable energy sources to grow. This evidence suggests that the renewable energy public policies in the Mercosur countries converge to a green economy, where the consumption of energy is based on renewable sources such as hydropower, biofuels, and wind (ATTIAOUI et al., 2017). Moreover, other authors suggest that this bi-directionality between the variables is related to the enormous abundance of renewable sources (e.g., hydropower, photovoltaic, solar, wind, biomass) that consequently stimulates the investments and development of renewable energy technologies and therefore the economic growth (FUINHAS et al., 2017).

The bi-directional causality among urbanization, consumption of renewable energy and economic activity is caused by economic development that consequently influences the urbanization process in the Mercosur countries (FRANCO et al., 2017). According to KOENGKAN (2018b) the growth in the urbanization process in these countries is due to the new agricultural technology's introduction, and the industrialisation development, that has provoked a restructuring of rural economies. Moreover, consequently, this process markedly induces economic growth and therefore, the consumption of energy (WANG et al., 2016). According to JEBLI and YOUSSEF (2016), the bi-directional relationship between agriculture production and economic growth in the Mercosur countries is due to the agriculture production depends on another economic sector in Mercosur trade-bloc like the non-manufacturing sector. Moreover, in these countries, agriculture products represent an outstanding share of the exported, where Argentina, Brazil, and Uruguay are essential commodities (e.g., agriculture products) exporters in the world. The agriculture production exerts a positive impact on economic activity and consequently in the consumption of energy. The existence of a bi-directional relationship between agriculture production and consumption of renewable energy means that the increase of agriculture production can contribute to increasing of consumption of renewable energy, as well as the rise in the investment and consumption of renewable energy increase the economic growth and consequently the agriculture production. Finally, the unidirectional causality between urbanization and agriculture production is due to the economic growth increase the process of urbanization and therefore the agriculture production. Moreover, this find is exciting because it is the first investigation the focusing this relationship among these two variables in a group of countries in the Latin America region.

This section showed the empirical results and the possible explanations for the bi-directionality and unidirectionality between renewable energy, economic growth, agricultural sector, and urbanization, in the countries from Mercosur trade-bloc. The next section will show the conclusion, policy implications of this investigations.

6. Conclusions and policy implications

The goal of this paper is detecting the causality between renewable energy, economic growth, agricultural sector and urbanization in Mercosur countries from 1980 to 2014. One of the reasons is that there is an absence of research that looks into the relationship in Mercosur trade-block countries. Another important reason is that renewable energy, urbanization and agricultural variables are scarcely studied together. Mercosur countries are characterised by renewable energy production and by agricultural tradition in the economy.

The PVAR regression revealed to be a valuable tool to analyse Mercosur complexities as the results appoint for the presence of endogeneity (the blocks of exogeneity, for all variables in the PVAR equation, are statistically significant at 1% level). The PVAR also revealed an intricate Granger causality panorama as was found bi-directional causality, between consumption of renewable energy, urbanization, agriculture production, and economic growth; and unidirectional causality from urbanization to agriculture production.

That findings are significant to the policymakers because the renewables energy consumption may affect the economic activity in Mercosur countries. The results suggest that government policies aimed at the creation of a mechanism to incentive the production and consumption of renewable energy. It is crucial for the creation of partnerships between the public and private sector, and the establishment of renewable energy portfolio standards. Further, the results indicate that energy policies should recognise the differences in the relationship between renewable and non-renewable and GDP. While Mercosur countries depending on renewable energy consumption to grow, may not depend on non-renewable energy because of the improvement of energy efficiency and environmental policies. Then, disaggregated analyses, by renewable energy consumption, contribute to guiding the energy policy.

References

ABOSEDRA, S.; BAGHESTANI, H.New Evidence on the causal relationship between the United States. **The Journal of Energy and Development**, v.14, n.2, p.285-292, 1989.

ABRIGO, M.R.M.; LOVE, I. Estimation of Panel Vector Autoregression in Stata: A Package of Programs. **The University of Hawai`i at Mānoa Department of Economics**, Working Paper Series, URL: http://www.economics.hawaii.edu/research/working.papers/WP 16-02.pdf., 2015.

AIS . AIS comercial do acordo de associação em negociação entre a comunidade européia e o mercosul: estudo do setor agrícola. **The university of Manchester**, p.1-5, 2007.

AL-IRIANI, M., Energy-GDP relationship revisited: An example from GCC countries using panel causality. **Energy Policy**, v.34, n.17, p.3342-3350, 2006.

AL-MULALI, U.; FEREIDOUNI, H.; LEE, J. Electricity consumption from renewable and non-renewable sources and economic growth: Evidence from Latin American countries. **Renewable and Sustainable Energy Reviews**, v.30, p.290-298,2014.

AMRI, F. The relationship among energy consumption (renewable and nonrenewable), and GDP in Algeria. **Renewable and Sustainable Energy Reviews**, v.76, p.62-71, 2017.

ANTONAKAKIS, N.; CHATZIANTONIOU, L.; FILIS, G. Energy consumption, CO2 emissions, and economic growth: An ethical dilemma. **Renewable and Sustainable Energy Reviews**, v.68, n.1., p.808-824, 2017.

ASAFU-ADJAYE, J. The relationship between energy consumption, energy prices, and economic growth: time series evidence from Asian developing countries. **Energy Economics**, v.22, n.6., p.615-625, 2000.

ATTIAOUI, I.; TOUMI, H.; AMMOURI, B.; GARGOURI I. Causality links among renewable energy consumption, CO2 emissions, and economic growth in Africa: evidence from a panel ARDL-PMG approach. **Environmental Science and Pollution Research**, v.24, n.14, p.13036-13048, 2017.

AVIAL, A.F.D.; ROMANO, L.; GARAGORY, F. Agricultural Productivity in Latin America and the Caribbean and Sources of Growth. **In Handbook of Agricultural Economics, Burlington**: Academic Press, pp. 3713-3768, 2010.

BAKIRTAS, T.; AKPOLAT, A. The relationship between energy consumption, urbanization, and economic growth in new emerging-market countries. **Energy**, v.147, p.110-121, 2018.

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

BELSLEY, D.A.; KUH, E.; WELSCH, E.R. Regression Diagnostics: Identifying Influential Data and Sources of Collinearity. **New York: Wiley**, 1980.

BHATTACHARYA, M.; PARAMATI, S.; OZTURK, I.; BHATTACHARYA, S. The effect of renewable energy consumption on economic growth: Evidence from the top 38 countries. **Applied Energy**, v.162, p.733-741, 2016.

BINDER, M.; HSIAO, C.; PESARAN, M.H. Estimation and inference in short panel vector auto-regressions with unit roots and cointegration. **Econometric Theory**, v.21, n.4., p.795-837, 2005.

BOWDEN, N.; PAYNE, J. The causal relationship between U.S. energy consumption and real output: A disaggregated analysis. **Journal of Policy Modeling**, v.31, n.2., p.180-188, 2009.

BRÜCKNER, M., Economic growth, size of the agricultural sector, and urbanization in Africa. **Journal of Urban Economics**, v.71, p.26-36, 2012.

ESEN, Ö.; BAYRAK, M. Does more energy consumption support economic growth in net energy-importing countries? **Journal of Economics, Finance and Administrative Science**, v.22, n.42., p.75-98, 2017.

FALLAHI, F. The causal relationship between energy consumption (EC) and GDP: A Markov-switching (MS) causality. **Energy**, v.36, n.7., p.4165-4170, 2011.

FRANCO, S.; MANDLA, V.R.; RAO, K.R.M. Urbanization, energy consumption, and emissions in the Indian context: A review. **Renewable and Sustainable Energy Reviews**, v.71, p.898-907, 2017.

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.

GENGENBACH, C.; PALM, F.C.; URBAIN; J-P. Panel Unit Root Tests in the Presence of Cross-Sectional Dependencies: Comparison and Implications for Modelling. **Department of Quantitative Economics, Universiteit Maastricht, The Netherlands**, p.1-33, 2008.

HANSEN, L.P. Large sample properties of generalized method of moments estimators. **Econometrica**, v.50, n.4., p.1029-1054, 1982. URL: <http://www.jstor.org/stable/1912775>.

HOLTZ-EAKIN, D.; NEWEY, W.; ROSEN, H.S. Estimating vector autoregressions with panel data. **Econometrica**, v.56, n.6, p.1371-1395, 1988. URL:http://www.jstor.org/stable/1913103.

INTERNATIONAL ENERGY ADMINISTRATION (IEA) ,2018. URL:https://www.iea.org/.

JEBLI, M.B.; YOUSSEF, S.B. Renewable energy consumption and agriculture: evidence for cointegration and Granger causality for Tunisian economy**. International Journal of Sustainable Development & World Ecology**, v.24, n.2., p.1745-2627, 2016.

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

KOENGKAN, M. The positive impact of trade openness on the consumption of energy: Fresh evidence from Andean community countries. **Energy**, v.158, p.936-943, 2018c.

KOENGKAN, M.; LOSEKANN, L.D., FUINHAS, J.A. The relationship between economic growth, consumption of energy, and environmental degradation: renewed evidence from Andean community nations. **Environment Systems and Decisions**, pp.1-13, 2018a.

KRAFT, J.; KRAFT, A. On the Relationship between Energy and GNP. **Journal of Energy Development**, v.3, p.401-403, 1978.

LIN, B.; MOUBARAK, M. Renewable energy consumption-Economic Growth nexus for China. **Renewable and Sustainable Energy Reviews**, v.40, p.111-117, 2014.

LIU, H.; KIM, H. Ecological Footprint, Foreign Direct Investment, and Gross Domestic Production: Evidence of Belt & Road Initiative Countries. **Sustainability**, v.10, n.10, p.1-28, 2018.

LOVE, I.; ZICCHINO, L. Financial development and dynamic investment behaviour: Evidence from panel VAR. **The Quarterly Review of Economics and Finance**, v.6., p.190–210, 2006.

MARTINS, M.L.R.. Meio ambiente e morada social nos países do Mercosul. Madrid, pp.303-313, 2002.

MINISTRY OF FOREIGN AFFAIRS. Mercosur, 2018. URL:http://www.itamaraty.gov.br/en/politica-externa/integracao-regional/6347-mercosur-en.

NASREEN, S.; ANWAR, S.The causal relationship between trade openness, economic growth, and energy consumption: A panel data analysis of Asian countries. **Energy Policy**, v.69, p.82-91, 2014.

O'BRIEN, R.M., A caution regarding rules of thumb for variance inflation factors. **Quality and Quantity**, v.41, n.5, p.673–690, 2007.

OCAL, O.; ASLA, A. Renewable energy consumption-economic growth nexus in Turkey. **Renewable and Sustainable Energy Reviews**, v.28, p.494-499, 2013.

OZTURK, I.; ACARAVCI, A. CO2 emissions, energy consumption and economic growth in Turkey. **Renewable and Sustainable Energy Reviews**, v.14, p.3220-3225, 2010.

PAO, H.-T.; FU, H. The causal relationship between energy resources and economic growth in Brazil. **Energy Policy**, v.61, p.793-801, 2013.

PESARAN, M.H., A simple panel unit root test in the presence of cross-section dependence. **Journal of Applied Econometrics**, v.22, n.4., p.256-312, 2007.

RADDATZ, C. Are external shocks responsible for the instability of output in low-income countries? **Journal of Development Economics**, v.84, n.1., p.155-187,2007.

SADORSKY, P., The impact of financial development on energy consumption in emerging economies. **Energy Policy**, v.38, p.2528–2535, 2010.

SANTOS, H.Energy Security in MERCOSUR+2: challenges and opportunities. **OIKOS**, v.14, n.2., p.05-18, 2015.

SOYTAS, U.; SARI, R. Energy consumption and GDP: causality relationship in G-7 countries and emerging markets. **Energy Economics**, v.25, p.33-37, 2003.

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.

WANG, Y.; CHEN, L.; KUBOTA, J. The relationship between urbanization, energy use, and carbon emissions: evidence from a panel of Association of Southeast Asian Nations (ASEAN) countries. **Journal of Cleaner Production**, v.112, n.2, p.1368-1374, 2016.

WORLD BANK DATA., 2018. URL:http://www.worldbank.org/.

Recebido em: 14/06/2020
Aceito em: 05/12/2020

Endereço para correspondência:
Nome Yormy Eliana Poveda
Email yemelop@gmail.com