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Does financial openness increase environmental degradation? Fresh evidence from MERCOSUR countries

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Abstract
This article researches the impact of financial openness on environmental degradation in the MERCOSUR countries over the time spanning from 1980 to 2014. The Panel Autoregressive Distributed Lag (PARDL), in the form of Unrestricted Error Correction Model (UECM), was computed with the purpose of decomposing the total effects of variables in their short- and long-run ones. The results of short-run impacts and elasticities of PARDL model showed that the financial openness increases the CO_2 emissions both in the short- and in the long-run. Moreover, the results also support that economic growth, consumption of primary energy, and agricultural production are responsible for an increase of emissions in the MERCOSUR countries. Therefore, these empirical findings will help expand the literature that assesses the impact of financial development on the environment. The results also point out to the need of policymakers to change the way the energy mix is financed.

Keywords Agricultural production · Environmental degradation · Energy economics · Economic growth · Financial openness

Introduction

The carbon dioxide (CO_2) emissions in the Latin America region have grown since 1950, having reached 451 million metric tons of emissions in 2008 (Koengkan 2018a). In the MERCOSUR, an acronym which stands for "Mercado Común del Sur" in Spanish, Brazil is the only country of the group that is ranked among the 20 highest CO_2 emitter countries in the world. In 2008, the country accounted for 52.6% of CO_2 emissions in the whole Latin America region (Boden et al. 2011). Other countries from MERCOSUR emit more than 10 million metric tons of CO_2 annually, such as Argentina (52.4), Venezuela (46.2), Paraguay (15.6), and Uruguay (10.5) (Boden et al. 2011). Moreover, the increase in the emissions in the Latin America region is caused by

consumption of energy where fossil sources account for 68.4% of the total emissions (Boden et al. 2011).

During the period from 1971 till 2013, the energy consumption in the Latin America region yielded an average annual growth rate of 5.4%, while the gross domestic product (GDP) was 3.0% (Balza et al. 2016). That is, the consumption of energy and GDP in the Latin America region have more than tripled over the past 40 years, where the consumption of energy was 248 million tonnes of oil equivalent (MTOE) in 1971, and 848 MTOE in 2013. In the same time period, the GDP per capita was US$ 668.60 and US$ 10,157.60, respectively (World Bank Data 2018). The increase in energy consumption and GDP in the Latin America region is related to the rapid process of financial, trade, and economic openness caused by several political transitions and economic reforms held in the last 40 years. These changes do exert a significant impact on the environment and thus need to be studied accordingly.

The impact of financial openness on CO_2 emissions has received great attention from researchers in the recent decades. The relationship between environmental degradation and economic activity has been explained in the recent years by the Environmental Kuznets Curve (EKC), which is an inverted-U nexus between economic growth and emissions of CO_2 (e.g., Kuznets 1955; Grossman and Krueger 1993). Several attempts have been made in the literature with the aimed at

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determining the dynamic relationship between environmental quality and economic activity (Saidi and Mbarek 2017). In these attempts to find new relationships between environmental degradation and economy according to the literature, several new variables are assessed in order to explain this nexus, such as urbanization, globalization, trade openness, and financial openness. However, the impact of financial openness on the degradation of the environment has received little importance. Nevertheless, in the scarce literature available on the subject, one could identify some different pathways that could be effective in the environment, namely:

- Financial openness increases the supply of credit and reduces the financial costs; consequently, it encourages the consumption and the investments made by firms and households, which cause CO_2 emissions (Sadorsky 2010);
- Financial openness encourages the investments in green technologies with high energy efficiency, thus ultimately improving the environment (Tamazian and Rao 2010; Tamazian et al. 2009).

What is the impact of financial openness on CO_2 emissions in the MERCOSUR countries? This query is the central question of this paper. The main aim of this study is to investigate the impact of financial openness on the environmental degradation of five MERCOSUR countries, over the period from 1980 to 2014. A Panel Autoregressive Distributed Lag (PARDL), in the form of Unrestricted Error Correction Model (UECM), will be used, aimed towards decomposing the total effects of variables in their short- and long-run parts. Several authors who have studied the impact of financial openness on environmental degradation have actually used this same approach (e.g., Bekhet et al. 2017; Abbasi and Riaz 2016; Boutabba 2014; Islam et al. 2013; Shahbaz et al. 2013a, c, d).

This article provides new findings with respect to the dynamic relationship between financial openness, economic growth, energy consumption, agricultural production, and CO_2 emissions with the purpose of helping policymakers in designing the implementation of effective environmental and economic policies for the MERCOSUR countries.

This article is organized as follows. Section 2 presents the summary of the literature. Section 3 provides the data. Section 4 presents the method used. Section 5 shows the empirical results. Section 6 focuses on the discussions of results. Finally, section 7 stresses the conclusions and policy implications from the research.

Literature review

The impact of financial openness or development on the environmental degradation has been increasingly a hot topic in the recent literature on economics and the environment (Saidi and Mbarek 2017). Indeed, several investigations have used different variables to explain the impact of human activity on the environment, such as primary energy consumption, consumption of renewable and fossil sources, GDP, trade openness, globalization index, CO_2 emissions (as a proxy of environmental degradation), exports, imports, urbanization, and agricultural production (e.g., Koengkan 2017, 2018a; Fuinhas et al. 2017). Moreover, some studies have used financial variables to explain this same impact. For example, foreign direct investment (FDI), financial growth, financial development, and financial openness development were used by Chinn and Ito (2008), Koçak and Şarküneşi (2018), and You et al. (2015). Additionally, several studies have discussed the importance of this variable on the CO_2 emissions. Indeed, the impact of financial development on CO_2 emissions has been widely explored by several researchers (e.g., Koçak and Şarküneşi 2018; Bekhet et al. 2017; Dogan and Turkekul 2016; Saidi and Mbarek 2017; Dogan and Seker 2016; Abbasi and Riaz 2016; Chang 2015; Salahuddin et al. 2015; You et al. 2015; Boutabba 2014; Lau et al. 2014; Islam et al. 2013; Shahbaz et al. 2013a, b, c, d, e; Shahbaz 2013; Shahbaz et al. 2016; Ozturk and Acaravci 2013; Jalil and Feridun 2011; Tamazian and Rao 2010; Tamazian et al. 2009).

Some authors found that the financial development increases the environmental degradation (CO_2 emissions), since the financial development increases credit supply and reduces financial costs. Consequently, it encourages the consumption and investments made by firms and households, that will later increase the economic activity, and also the consumption of energy and natural resources. Subsequently, it increases the environmental degradation as widely recognized by several authors (e.g., Koçak and Şarküneşi 2018; Bekhet et al. 2017; Dogan and Turkekul 2016; Abbasi and Riaz 2016; Chang 2015; Boutabba 2014; Lau et al. 2014; Islam et al. 2013; Shahbaz 2013; Shahbaz et al. 2013e; Shahbaz et al. 2013; Shahbaz et al. 2016).

For other researchers, the financial openness decreases the environmental degradation. They claim that the financial openness encourages the investments, while the purchase of green technologies with high energy efficiency actually reduces the consumption of energy from fossil sources, thus consequently reducing the CO_2 emissions (e.g., Saidi and Mbarek 2017; Dogan and Seker 2016; Salahuddin et al. 2015; You et al. 2015; Ozturk and Acaravci 2013; Shahbaz et al. 2013b, c, d; Jalil and Feridun 2011; Tamazian and Rao 2010; Tamazian et al. 2009).

Data

In order to investigate the impact of financial openness on environmental degradation, five countries from MERCOSUR were selected, namely: Argentina, Brazil, Paraguay, Uruguay, and Venezuela (temporarily suspended). Moreover, the time span from 1980 to 2014, available for all variables of the study, was used. The MERCOSUR is an economic bloc in the South American region created in 1991, aimed at the promotion of free

trade and the fluid movement of goods and people among associate countries (Koengkan 2018a). The variables that will be used in this article are the following:

- Carbon dioxide emissions (CO_2) from consumption of energy (million metric tons), available from the International Energy Administration (IEA) (2018);
- Gross domestic product (GDP), in constant local currency units (LCU), available from the World Bank Data (WDB) (2018);
- Primary energy consumption (ENERGY), in a billion kilowatt-hour (kWh), from fossil and renewable sources, available from the International Energy Administration (IEA) (2018);
- Financial openness index (KAOPEN) that measures the country's degree of capital account openness, available from the Chinn-Ito index (KAOPEN) (2008)—this index is based on the binary dummy variables that codify the tabulation of restrictions on cross-border financial transactions reported in the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER);
- Agricultural production (AGRO) covering food crops that are considered edible and that contain nutrients, available from the World Bank Data (WBD) (2018).

The choice of the above-mentioned variables is due to the fact that the MERCOSUR is an economic bloc that

- Has experimented a rapid economic growth in the last 20 years, considering that today the bloc represents something equivalent to the fifth largest economy in the world, thus accounting for a GDP of US$ 2.7 trillion. Since its establishment creation, trade within MERCOSUR has multiplied by more than 12 times, soaring from US$ 4.5 billion in 1991 to a peak of US$ 57 billion in 2013 (MERCOSUR 2018);
- Since the 1980s has registered a rapid process of financial openness, namely by Argentina and Brazil (Quispe-Agnoli and McQuerry 2011);
- Has experienced a rapid energy consumption. The MERCOSUR is among the major energy producers in the world. The bloc holds 19.6% of the world's proven oil reserves, 3.1% of natural gas reserves, and 16% of recoverable shale gas reserves (MERCOSUR 2018). Moreover, the bloc is a leading world's producer of renewable energy, with the largest shares of renewable energy sources in the energy mix. The hydropower, biofuels, and biomass do have a large participation in the MERCOSUR's energy matrix (Koengkan 2018a);
- Has registered a rapid increase in the agricultural production, considering that the bloc is the leading world's producer and exporter of agricultural commodities (MERCOSUR 2018).

The agricultural production was included in this investigation since, according to the energy and environmental literature, agriculture actually stimulates the economic activity, the consumption of energy, the exploration of natural resources, and the soil, thus leading, as a consequence, to an increase in environmental degradation. The inclusion of this variable in the model tries to capture this phenomenon.

The MERCOSUR members share the same social and economic structure, colonial history, geography, have an enormous abundance of natural resources, and a large consumer market. In the last 30 years, this group of countries has experienced a rapid process of economic, trade, and financial openness, together with social transformation caused by several political transitions and economic reforms. All these characteristics make the MERCOSUR region an exceptional place in the world to investigate issues related to social/political, economic and financial activity, and environmental degradation. Together, these motives justify the choice of these countries and the opportunity to carry out this investigation. Table 1 shows the descriptive statistics of variables in the logarithms (Ln) and in the first-differences (Δ).

The emissions of CO_2, primary energy consumption, and GDP were transformed in per capita values. Indeed, the per capita values let us control the disparities in the population growth over time and among the countries (Koengkan 2018a; Koengkan 2018b; Fuinhas et al. 2017). The option for using constant GDP in local currency units (LCU), instead of constant US dollars, does attenuate the influence of both the inflation and the changes in the exchange rates (Koengkan 2018). The GDP in constant (LCU) was used by several authors who have investigated the Latin America region (Koengkan 2018a; Fuinhas et al. 2017; Koengkan 2017). In addition, the GDP in constant US dollars has been previously

Table 1 Descriptive statistics

Variables	Descriptive statistics				
	Obs.	Mean	Std.-Dev.	Min.	Max.
$LnCO_2$	175	− 13.0971	0.8080	− 14.8064	− 11.9527
LnENERGY	175	− 16.6636	0.5055	− 18.6642	− 15.9598
LnGDP	174	10.5056	2.6257	7.2285	15.2759
LnKAOPEN	175	0.3360	0.2330	0.0000	0.6931
$ΔLnCO_2$	170	0.0072	0.0769	− 0.2775	0.2649
ΔLnENERGY	170	0.0217	0.0991	− 0.2095	0.6856
ΔLnGDP	169	0.0101	0.0500	− 0.1264	0.1503
ΔLnKAOPEN	170	− 0.0013	0.0887	− 0.4113	0.4113
ΔLnAGRO	170	0.0197	0.1053	− 0.4089	0.4835

"Ln" and "Δ" variables in the natural logarithms and the first-differences of logarithms; *Obs.* number of observations in the model; *Std.-Dev.* standard deviation; *Min.* and *Max.* minimum and maximum, respectively. The command *sum* of Stata was used for descriptive statistics

tested, and this variable does not cause a statistically significant impact. Additionally, the number of observation, 174 and 169, in the variable GDP, both in the logarithms and the first-differences is due to the lack of available data in 2014 for Venezuela. This country has been suffering a severe financial and political crisis and did not make its GDP data available for 2014. Thus/therefore, the agricultural production in the logarithms has not been computed in the descriptive statistics because the variable does not cause any impact on CO_2 emissions and so was removed from the model. Next, we will be presenting the technique that was applied in this investigation.

Method

The PARDL approach, in the form of UECM, was used to investigate the impact of financial liberalization on environmental degradation in the MERCOSUR's countries. This model has been proposed by Engle and Granger (1987) and Granger (1981) and later improved by Johansen and Juselius (1990), with the introduction of cointegration techniques, as well as reparametrizing them to an ECM. The PARDL model can produce consistent estimates for the long-run that are asymptotically normally distributed. Pesaran et al. (2001) add that the PARDL model is robust in the presence of endogeneity between the variables considering that it is free of serial correlation presence. Moreover, the PARDL model is flexible 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 variables to be unequivocally I(1) (Menegaki et al. 2017). Furthermore, the FMOLS, DOLS, and GMM were tested and proved to be inadequate for the completion of this study. Additionally, the PARDL in the form of UECM allows to differentiate among the short- and the long-run Granger causality (e.g., Koengkan 2018a; Menegaki et al. 2017; Fuinhas et al. 2017). For these reasons, the PARDL model was chosen for carrying out this investigation. The PARDL in the form of UECM complies with the following general equation:

$$\Delta LnCO_{2it} = a_i + \sum_{j=1}^{k} \gamma_{2it} \Delta LnENERGY_{it-j} + \sum_{j=1}^{k} \gamma_{3it} \Delta LnGDP_{it-j}$$
$$+ \sum_{j=1}^{k} \gamma_{4it} \Delta LnKAOPEN_{it-j} +$$
$$\sum_{j=1}^{k} \gamma_{5it} \Delta LnAGRO_{it-j} + \beta_{1it} LnCO_{2it-1} + \beta_{2it} LnENERGY_{it-1}$$
$$+ \beta_{3it} LnGDP_{it-1} + \beta_{4it} LnKAOPEN_{it-1} + \varepsilon_{it}$$

$$(1)$$

where α_i denotes intercept, $\beta_{2it}...\beta_{4it}$, $k = 1,...,m$ are estimated parameters, as ε_{1it} is error term. Moreover, the "Δ" and "Ln" denote the short-run impacts and long-run (elasticities) of the variables. Therefore, before the PARDL regression, it is recommended that the preliminary tests are applied so as to verify the characteristics of variables (Koengkan 2018a). Bearing this in mind, some preliminary test will be applied, such as follows:

- Cross-sectional dependence (CSD-test) to verify the existence of cross-section dependence. The null hypothesis is the presence of CSD in the variables (Pesaran 2004);
- Variance inflation factor (VIF) to check the existence of multicollinearity between the variables;
- 2nd generation unit root test (CIPS-test) (Pesaran 2007) to check the existence of unit root. The null hypothesis is the rejection that the variable is I(1);
- 2nd generation cointegration Westerlund (2007) test to verify the presence of cointegration. The null hypothesis is the non-presence of cointegration. The Westerlund cointegration test requires that all variables of the model be I(1) (e.g., Koengkan 2018a; Fuinhas et al. 2017);
- Mean group (MG) or pooled mean group (PMG) estimators to check the heterogeneity of parameters in the variables, in the short- and long-run. The MG is an estimator that compute the average coefficients of all individuals in regression (e.g., Koengkan 2018a; Fuinhas et al. 2017). Besides this estimator being consistent, in the presence of slope homogeneity it tends to be inefficient (Pesaran et al. 1999). The PMG estimator is more efficient when compared to MG, in the presence of homogeneity. This estimator can make restrictions among cross-sections, together with the adjustment speed term (Fuinhas et al. 2017).

After carrying out the preliminary tests, the specification's tests were applied so as to examine the characteristics of the models. For this purpose, some specification tests will be used, such as follows:

- Friedman test to check the presence of cross-sectional dependence (Friedman 1937). The null hypothesis rejection of this test is that the residuals are not correlated;
- Breusch and Pagan Langrarian Multiplier test to measure whether the variances across individuals are correlated (Breusch and Pagan 1980);
- Wooldridge test (Wooldridge 2002) to check for the existence of serial correlation;
- Modified test (Greene 2002) to check the presence of groupwise heteroskedasticity.

Results

This section presents the outcomes of preliminary and specification tests, results from the PARDL model, short-run impacts, elasticities, and adjustment speed. To verify the

Table 2 VIF and CSD-test

Variables	VIF	1/VIF	Mean VIF	CD-test	p value	
$LnCO_2$	n.a.			8.14	0.000	***
LnENERGY	1.27	0.7862		12.89	0.000	***
LnGDP	1.36	0.7359		13.74	0.000	***
LnKAOPEN	1.18	0.8474	1.27	4.57	0.000	***
$\Delta LnCO_2$	n.a.			1.65	0.099	*
ΔLnENERGY	1.05	0.9522		1.73	0.084	*
ΔLnGDP	1.28	0.7793		7.29	0.000	***
ΔLnKAOPEN	1.05	0.9541		0.15	0.881	
ΔLnAGRO	1.20	0.8341	1.15	3.88	0.000	***

***, *Statistically significant at 1% and 10% levels, respectively; (Ln and Δ) denote variables in the natural logarithms and the first-differences of logarithms; the command *xtcd* of Stata was used

presence of multicollinearity and cross-sectional dependence, the VIF and CSD-test were computed. Table 2 highlights the results of both VIF and CSD-test.

The outcomes of Mean VIFs indicate that according to the variables in the natural logarithms, the multicollinearity was 1.27, while the variable was 1.15 in the first-differences; both results are below the benchmark of 10 established by VIF-test. The CSD-test exams the evidence of the presence of cross-sectional dependence in all variables, with the exception of the financial openness, in the first-differences. In the presence of low-multicollinearity and cross-sectional dependence, the econometric literature recommends examining the stationarity of variables so as to stress whether the variables are non-stationary [I(1)] or stationary [I(0)] (Koengkan 2018a).

Table 3 Unit root test

Variables	2nd generation unit root test					
	Pesaran (2007) Panel Unit Root test (CIPS) (Zt-bar)					
	Without trend			With trend		
	Lags	Zt-bar	p value		Zt-bar	p value	
$LnCO_2$	1	−1.471	0.071	*	−1.592	0.056	*
LnENERGY	1	−0.622	0.267		−1.209	0.113	
LnGDP	1	1.705	0.956		0.208	0.582	
LnKAOPEN	1	−0.810	0.209		−0.108	0.457	
$\Delta LnCO_2$	1	−7.670	0.000	***	−6.769	0.000	***
ΔLnENERGY	1	−6.060	0.000	***	−5.164	0.000	***
ΔLnGDP	1	−5.296	0.000	***	−4.039	0.000	***
ΔLnKAOPEN	1	−5.678	0.000	***	−4.616	0.000	***
ΔLnAGRO	1	−7.176	0.000	***	−6.386	0.000	***

***, *Significant at 1% and 10% level, respectively; (Ln and Δ) denote variables in the natural logarithms and the first-differences of logarithms; null for CIPS tests: series is I(1); the lag length (1), and trend were used in this test

Table 4 Westerlund test

Westerlund test			
Statistics	Constant		
	Value	p value robust	
Gt	−3.454	0.017	**
Ga	−15.914	0.103	
Pt	−7.596	0.023	**
Pt	−15.105	0.127	

**Statistically significant at 5% levels; bootstrapping regression with 300 reps. H_0, no cointegration; H_1 Gt and Ga test the cointegration for each country individually, while Pt and Pa test the cointegration of the panel as a whole; the Stata command *xtwest* was used

Table 3 shows the results of the second generation unit root test (Pesaran 2007).

The CIPS-test was computed with lag length (1) both with and without the trend. The results of this test suggest that the variable CO_2 emissions in the natural logarithms and all variables in the first-differences are I(0), as expected. In order to check the presence of cointegration in the model, the second-generation cointegration Westerlund (2007) test was calculated. Table 4 shows the results of the Westerlund test.

The results of the Westerlund test seem to reject the existence of cointegration between the variables as expected. Indeed, the non-presence of cointegration among such variables points out to the use of an econometric technique that is stringent about integration variables, i.e., PARDL model (Fuinhas et al. 2017; Koengkan 2018a). Therefore, in order to check whether the model is heterogeneous, the mean group (MG) and pooled mean group (PMG) or dynamic fixed effects (DFE) ought to be tested. Table 5, below, shows the outcomes of estimated models and the outcomes of the Hausman test.

The results of both heterogeneous and Hausman tests indicate that the DFE estimator is the most suitable, i.e., that the panel is homogeneous. Consequently, when the panel is homogeneous this means that all variables share the common shocks among the countries in the panel (Koengkan 2018a). In order to check the characteristics of the model, the specification tests were performed. Table 6 shows the results of the specification tests.

The results of the specification tests show the existence of cross-sectional dependence, non-correlation among the

Table 5 Heterogeneous and Hausman tests

Hausman tests	MG vs PMG	PMG vs DFE	MG vs DFE
	$Chi^2(9) = -50.85$	$Chi^2(9) = -46.34$	$Chi^2(9) = 0.00$***

***Statistically significant at 1% levels; Hausman results for H_0: difference in coefficients not systematic; the Stata commands *xtpmg* and Hausman (with the options, sigmamore alleqs constant) was used

Table 6 Specification tests

Statistics	Friedman test	Breusch and Pagan LM test	Wooldridge test	Modified Wald test
	30.379***	$Chi^2(10) = 13.874$	$F(1,4) = 15.935$**	$Chi^2(5) = 99.37$***

***, **Significant at 1% and 5% level, respectively; 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

variables, serial correlation in the panel data, and the presence of heteroskedasticity. The literature on econometric recommends to use the Driscoll and Kraay (D.K.) estimator in the presence of cross-sectional dependence, serial correlation, and heteroskedasticity (Koengkan 2018a; Fuinhas et al. 2017). This estimator is a matrix estimator that generates robust standard errors for several phenomena found in the sample errors. The same author also adds that the D.K. estimator is highly significant if compared with FE and FE-Robust estimators. Because of this, the DFE-D.K. (Driscoll and Kraay) was chosen as the only estimator in our investigation. Table 7 shows the estimation results of the PARDL model.

Table 7 presents the FE D.K. estimator of the PARDL model. The outcomes of variables in the PARDL model are statistically significant (see Table 7). The short-run impacts and elasticities (long-run) in the PARDL model are presented in Table 8, below.

The short-run impacts have not been directly observed on estimates, while the long-run (elasticities) were computed by dividing the coefficients of the independent variables by the coefficient of dependent variables "$LnCO_2$", both lagged once, and then multiplying the ratio by (− 1). Therefore, as expected, the economic growth, consumption of primary energy, and financial openness increase the environmental degradation (CO_2 emissions) in the short- and

in the long-run, while agricultural production produces the same affect but only in the short-run.

Discussion

The impact of financial openness on environmental degradation (CO_2 emissions) in the MERCOSUR countries expands the existing literature approaching such impact. Therefore, the results point out to the presence of cross-sectional dependence, low-multicollinearity, unit roots in the variables, cointegration, and homogeneity in the PARDL model (see Tables 2, 3, 4, and 5). The specification tests suggest the existence of cross-sectional dependence, non-correlation among the variables, serial correlation in the panel data, and the presence of heteroskedasticity (see Table 6). The non-existence of a correlation between countries in the study, as argued by Breusch and Pagan Langrarian Multiplier test, is due to the different economic structures of each country (Koengkan 2018a).

The outcomes of short-run impacts and elasticities (long-run) of the PARDL model are statistically significant in the FE-D.K. estimator. The results also indicated that the economic growth increases the CO_2 emissions 0.3953 in the short-run, and 0.6697 in the long-run. The primary energy consumption in the short-run increases the environmental degradation 0.1090, while such increase in the long-run is 0.1809. Moreover, the financial openness increases the emissions of

Table 7 Estimation results of PARDL model

Independent variables	Dependent variable ($\Delta LnCO_2$)	
	FE-D.K. (Driscoll and Kraay)	
Constant	− 8.1092	***
$\Delta LnGDP$	0.3953	**
$\Delta LnENERGY$	0.1090	*
$\Delta LnKAOPEN$	0.1191	**
$\Delta LnAGRO$	0.0939	**
$LnCO_2$	− 0.4721	***
$LnGDP$	0.3162	***
$LnENERGY$	0.0854	**
$LnKAOPEN$	0.0743	*
	Statistics	
N	169	
F	41.8061	

***, **, *Statistically significant at 1%, 5%, and 10% level, respectively; the Stata command *xtscc* was used; (Ln and Δ) denote variables in the natural logarithms and the first-differences

Table 8 Short-run impacts, elasticities, and adjustment speed of the PARDL model

Independent variables	Dependent variables ($\Delta LnCO_2$)	
	FE-D.K. (Driscoll and Kraay)	
Constant	− 8.1092	***
$\Delta LnGDP$	0.3953	**
$\Delta LnENERGY$	0.1090	*
$\Delta LnKAOPEN$	0.1191	**
$\Delta LnAGRO$	0.0939	**
ECM	− 0.4721	***
$LnGDP$	0.6697	***
$LnENERGY$	0.1809	***
$LnKAOPEN$	0.1574	***

***, **, *Statistically significant at 1%, 5%, and 10% levels, respectively; the Stata command *xtscc* was used; (Ln and Δ) denote variables in the natural logarithms and the first-differences

CO_2 by 0.1191 and 0.1574 in the short- and long-run, respectively. The agricultural production increases the environmental degradation by 0.0939 in the short-run.

Bearing this in mind, the increase of environmental degradation through economic growth seems to be in line with several researchers who have investigated the impact of economic activity on CO_2 emissions (Koengkan 2018a; Fuinhas et al. 2017; Paramati et al. 2017; Pablo-Romero and Jésus 2016; Saidi and Hammami 2015; Omri et al. 2014). In the words of Said and Hammami (2015), the increase of environmental degradation is caused by the dependence on fossil sources. The economic growth promotes the consumption of this kind of source, and consequently intensifies the emissions of CO_2. This idea is accepted by Fuinhas et al. (2017), who confirm that the Latin American countries have a high dependency on fossil fuels. In fact, some countries of this region are major oil producers, while others are major importers of this kind of resource. However, Omri et al. (2014) have a different vision about the increase of environmental degradation in the MERCOSUR countries. For these authors, the economic capitalization, trade development, and development of infrastructure stimulate the economic activity, and consequently, the consumption of energy from fossil sources. The incremental impact of consumption of primary energy on CO_2 emissions is in line with the conclusions found by several studies (e.g., Koengkan 2018; Charfeddine 2017; Shahbaz et al. 2016; Fuinhas et al. 2017; Pablo-Romero and Jésus 2016; Saidi and Hammami 2015; Omri et al. 2014). As previously reported by Koengkan (2018a), Fuinhas et al. (2017), Saidi and Hammami (2015), and Omri et al. (2014), the increase of emissions in CO_2, in the MERCOSUR countries, is due to the economic dependence on fossil sources. In the energy matrix of Latin American countries, the fossil fuel sources do have a large share.

The increase of environmental degradation through financial openness is in line with the findings by some authors (e.g., Bekhet et al. 2017; Dogan and Turkekul 2016; Abbasi and Riaz 2016; Chang 2015; Boutabba 2014; Lau et al. 2014; Islam et al. 2013; Shahbaz 2013). According to Shahbaz et al. (2013a) and Islam et al. (2013), the cheaper credit caused by financial openness increases the purchase of appliances, autos, homes, and investments by firms, and households alike. This increase exerts a stimulus on economic activity, and consequently in the consumption of fossil fuels. Chang (2015) shares the same vision and confirms that the increase in domestic credit, through financial openness, makes both households and

firms more prone to expand the economic activity and energy demand, and, consequently, the environmental degradation. Another explanation for the increase in CO_2 emissions is related to the inability of the paradigm change in energy sources. Indeed, the financial liberalization, via trade openness probably encourages investments in fossil fuels more than in renewables sources. Based on these former literature accounts, we can summarize the impact of financial openness on environmental degradation (CO_2 emissions), as shown in Fig. 1.

The increasing impact of agricultural production on CO_2 emissions is confirmed by some authors (e.g., Pryor et al. 2017; Vlontzos and Pardalos 2017). According to Pryor et al. (2017), the mechanization of agriculture production does contribute to the increase in the consumption of energy from fossil sources and consequently also increases the greenhouse gas emissions. Another possible explanation is that, in the MERCOSUR area, agriculture has been expanding rapidly. However, this growth increases deforestation, and, consequently, the emissions of CO_2 in the long-run.

Finally, the ECM parameter of PARDL model is statistically significant at 1% (-0.4721). When an ECM parameter is negative and statistically significant, it is very similar for testing Granger causality according to the conventional form (e.g., Koengkan 2018a; Fuinhas et al. 2017). The ECM version of Granger causality and cointegration can ensure that both magnitudes of effects and causality are revealed by their own elasticity (see Table 8). Although using this method lets us conclude about the relations of causality established between the variables, the objective of this paper is not to proceed with the analysis of such causality.

Conclusions and policy implications

This study is focused on the analysis of the impact of financial openness on environmental degradation (CO_2 emissions) in five MERCOSUR countries, over the period from 1980 to 2014. A PARDL model, in the form of UECM, was used as the econometric methodology. The results of preliminary tests have proven the existence of low-multicollinearity between the variables, cross-sectional dependence, unit roots, and also that the panel data is homogeneous. Moreover, the specification tests suggested the presence of cross-sectional dependence, non-correlation, serial
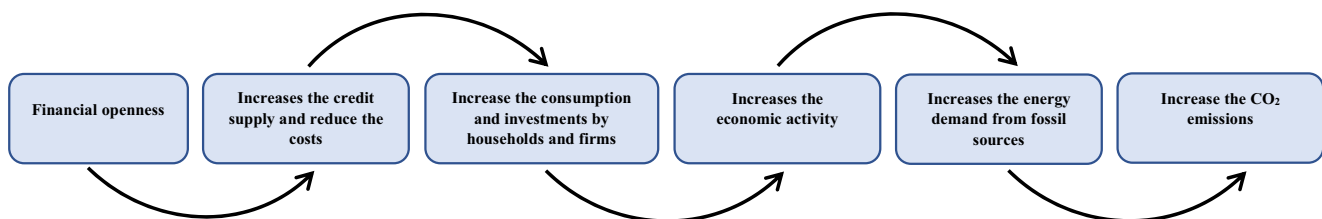

Fig. 1 Summary of the impact of financial openness on environmental degradation

correlation in the panel data, together with heteroskedasticity in the model.

The results of short-run impacts and elasticities of PARDL model have confirmed that the financial openness increases the environmental degradation in the MERCOSUR countries both in the short- and in the long-run. This increase is due to the impact of financial openness on economic activity and the consumption of energy from fossil sources, and, ultimately, such impact eventually increases the emissions of CO_2. The results of short-run impacts and long-run elasticities prove that the MERCOSUR's countries are dependent on fossil sources. Indeed, the economic activity of these countries is based on non-renewable sources to grow. As a consequence, the consumption of energy, economic growth, and the agricultural production increase the emissions of CO_2.

Based on these results, we should like to made the following remarks: (i) create conservation policies that will reduce the consumption of energy, although it is expected that these policies do not hamper the economic activity; (ii) create new renewable energy policies that will boost investments and consumption of alternative energy sources; and (iii) encourage public and private financial institutions to give special loan discounts to firms and households that are interested in investing or developing and purchase green technologies. These changes and policies will be able to increase the consumption of renewable energy and the economic activity due to the new investments made in this kind of source, while reducing the consumption of energy and dependence on fossil fuels, and, ultimately, the CO_2 emissions.

Finally, these empirical findings will help to expand literature dealing with the impact of financial development on the environment, as well as influencing policymakers to change the form of financing the energy matrix in the MERCOSUR countries.

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