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RESEARCH ARTICLE

Does financial openness cause the intensification of environmental degradation? New evidence from Latin American and Caribbean countries

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Abstract
The impact of financial openness on environmental degradation, mainly via carbon dioxide emissions, was investigated for a panel of 21 Latin American and Caribbean countries, throughout 35 years (from 1980 to 2014). An autoregressive distributed lag model was used to decompose the total effects of the variables into their short- and long-run components. The results show that financial openness, economic growth, and primary energy consumption increased environmental degradation, both in the short and long run, while renewable energy consumption decreased it. These findings suggest that policymakers should carry out financial reforms focused on sustainable development, as well as support renewable energy projects. Moreover, the results also lead one to believe that these countries' economic growth strategies should be integrated with the carbon dioxide emissions regulation.

Keywords Environmental degradation · Ecological economics · Financial development · Energy economics

JEL Classification F64 · G1 · N56 · O44 · Q50

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1 Introduction

Carbon dioxide (CO_2) emissions are considered a significant contributor to global warming, which is the greatest potential cause for climate change, as well as one of the most significant challenges that human society currently faces. The environmental problems that can arise from the carbon dioxide emissions (CO_2) growth led policymakers and scholars to discuss and develop strategies for reducing these emissions and, consequently, their impacts on global warming. Faced with these significant problems, many nations committed themselves to the decrease of their greenhouse gas emissions, signing the widely known "Kyoto Protocol". For these countries to reach this goal, it is necessary to identify the significant determinants of CO_2 emissions.

In the Latin American and Caribbean (LAC) countries, CO_2 emissions have been growing since 1950, reaching 451 million metric tons in 2008. Looking at these countries' performance, we see that Brazil and Mexico are among the 20 highest CO_2 emitters in the world and, in 2008, these two countries accounted for 52.6% of the region's CO_2 emissions (Boden et al. 2011). However, several other countries in the region emit more than 10 million metric tons of CO_2 annually, namely: Argentina (52.4), Chile (19.9), Colombia (18.5), Peru (11.1), Trinidad and Tobago (13.6), and Venezuela (46.2) (e.g. Boden et al. 2011). In the LAC region, liquid fuels account for 60.8% of total CO_2 emissions, with coal being only a modest contributor, with 7.6% (Boden et al. 2011).

Moreover, between 1971 and 2013, the gross domestic product (GDP) from the LAC countries had an average annual growth rate of approximately 3.0%, while energy consumption grew about 5.4% (Balza et al. 2016). In 1971, the LAC GDP per capita in US dollar was 668.60 US$, while in 2013 it was 10,157.60 US$ (World Bank Data 2018). Regarding LAC energy consumption, in 1971 it was 248 million tonnes of oil equivalent (MTOE), and in 2013 it was 848 MTOE, with an increase of 8% in global electricity demand over this period (Balza et al. 2016). As we can see, both the regional GDP and energy consumption have more than tripled over the past 40 years. This fact was mainly due to several economic reforms and political transitions, which have led to a bunch of economic and social transformations on the LAC region in the last 40 years.

Regarding the financial liberalisation in the LAC region, we can say that it went through a group of historical experiences over the past decade, which have defined the conventional wisdom on financial liberalisation and development in the region. The first one began in the 1960s and 1970s, during the period of import-substitution industrialisation, with the state controlling the financial sector. This situation is a resulted of substantial fiscal cost that is associated with mismanagement of public banks and financial sector (La Torre et al. 2012).

The second experience began in the 1980s, the so-called "lost decade", where the countries from this region suffered from an impressive inflation rise and stagnation in their economic growth, associated with the 1982–1989 debt crisis (Aizenman 2005). Indeed, the debt crisis changed the way the economic policy and management were handled in this region. The Brady plan is an example of the re-entry of capital inflows into the LAC countries in the early 1990s. This "fresh" start led the region to adopt a bunch of sweeping reforms. For example, Argentina, Brazil, and Mexico passed schemes of deep trade and financial liberalisation, with the privatisation of significant portions of the public sector, and with the development of economic stabilisation programmes (Aizenman 2005).

These reforms were based on the prerequisite that renewed external financing would stimulate the domestic saving, the investments, and consequently the economic growth of this region. The adoption of such reforms increased the LAC capital mobility from 40%, in the 1980s, to 75%, in the 1990s. These results have overcome the ones from other regions, such as Asia, where capital mobility went from about 40%, in the 1980s, to 60%, before the 1997 crisis, falling to 55% after the crisis. In the Middle East and North Africa, the increase in capital mobility was less pronounced, going from about 40 to 50% (Aizenman 2005). Indeed, it seems that the financial liberalisation in the LAC region has influenced the liberalisation in other continents. However, it also appears that these changes have had a significant impact on the LAC environment, since the region's environmental degradation has more than tripled (Bhattarai and Hammig 2001).

These characteristics (the LAC economic and social structures' rapid transformation) make this region an exceptional place to research issues related with the impact of human activities (e.g. financial liberalisation, energy consumption) on environmental degradation.

In recent decades, the impact of financial openness and financial liberalisation on environmental degradation (particularly, CO_2 emissions) has received considerable attention from researchers. Several attempts have been made in the economic and ecological literature to determine the dynamic nexus between economic activity and environmental quality (Saidi and Mbarek 2017). In these attempts, several new variables, such as globalisation, trade openness, urbanisation, and financial openness (e.g. Jugurnath and Emrith 2018; Saidi and Mbarek 2017), have been introduced in the estimations to understand and explain this causality in a more detailed way.

The results from previous studies point to some channels by which the financial sector can affect environmental quality. For example: (1) financial liberalisation increases the capital supply required by firms and households to invest and consume, and consequently leads to an increase in CO_2 emissions (e.g. Sadorsky 2010; Bekhet et al. 2016) and (2) financial openness promotes the investment in green technologies, as well as high energy efficiency, thus improving environmental quality (Tamazian and Rao 2010; Tamazian et al. 2009).

Based on this information, the central question of this article will be the following: What is the impact of financial liberalisation on the environmental degradation of the Latin American and Caribbean countries? The primary purpose of this study is to investigate the effects of financial openness on the environmental quality of 21 LAC countries, over a period ranging from 1980 to 2014. An autoregressive distributed lag (ARDL), in the form of an unrestricted error correction model (UECM), was used to decompose the total effects of the variables into their short- and long-run elasticities.

Indeed, this investigation is motivated firstly by deepening of knowledge about the possible impacts of financial openness on environmental degradation. Second, the financial openness that is a proxy of globalisation process and environmental degradation has been widely discussed in several international conferences and has gained great concern on the respective subjects from the civil society and governments. Third, the LAC countries are in process of financial liberalisation, and this is made necessary the realisation of this investigation.

This study can be considered a pioneer given that: (1) it uses a sample of LAC countries, which is a group not addressed in the literature on this topic; (2) it uses a financial openness variable, instead of the financial development index; (3) it uses the renewable energy consumption, which is essential to identify the effects of alternative energy sources on environmental degradation; (4) it includes impulse dummies to test the robustness of the model to economic shocks (an approach that is not common in investigations that research this topic); (5) it uses the Panel ARDL methodology (the previous literature just uses the ARDL bounds testing); and (6) it explains in a more complete way how the variables are related if compared with other investigations.

Moreover, this study can be considered relevant for the following reasons: (1) the empirical findings of this investigation will contribute to the scarce literature on the impact of financial openness on environmental degradation; (2) there is a need to comprehend how these variables interact in the LAC countries; and (3) it will help the LAC policymakers in the development of appropriate economic, energy, and environmental policies for their region.

This article is organised as follows. Section 2 presents a summary of the literature; Sect. 3 describes the method and description of variables that were used in this article; Sect. 4 shows the empirical results and discussion; and finally, Sect. 5 presents the conclusions and the policy implications.

2 Literature review

As we already stated, the ascertainment of the impact of financial openness on the environment has been garnering increasing attention in the recent economic and ecological literature (e.g. Saidi and Mbarek 2017). Authors have used variables such as financial development, financial growth, foreign direct investment (FDI), and the financial openness variable developed by Chinn and Ito (2008) (e.g. Jugurnath and Emrith 2018; Koçak and Şarkgüneşi 2018, You et al. 2015) jointly with a proxy of environmental degradation, usually CO_2 emissions (e.g. Koengkan 2018; Jamel 2017), in order to investigate this issue.

Although these authors have used different variables to represent financial openness/development, the decision on the best approach continues to be a puzzle. Despite this, it is essential to know what conclusions have been reached by the literature regarding the impact of financial openness/development on environmental degradation.

Regarding this previous question, we can start by saying that the literature on this relationship has evolved in two branches: one which argues that financial openness can reduce environmental degradation, and another which argues that financial openness has a detrimental effect on the environment. Table 1 shows the principal authors whose results support this second view.

As we have already explained, there is a bunch of reasons pointed out by the authors to justify their results. For instance, Abbasi and Riaz (2016) stated that financial development encouraged the investment in green technologies, which led to an increase in the production and consumption of renewable energy and, consequently, to a decrease in environmental degradation. This idea has also been accepted by some authors who reached the same conclusions using different variables, time spans, samples, and methodologies (e.g. Saidi and Mbarek 2017; Salahuddin et al. 2015).

Moreover, You et al. (2015) found that financial openness increased the credit supply, which, consequently, encouraged firms and households to purchase and invest in technologies with higher energy efficiency, reducing energy consumption, and thus environmental degradation. Similar conclusions were also drawn by Ozturk and Acaravci (2013), with their empirical results pointing out that financial development decreases environmental degradation in the long run (similar results were also found by Shahbaz et al. 2013a, b). Focusing their studies on China, Shahbaz et al. (2013d) and Jalil and Feridun (2011) also found evidence that financial development was able to reduce Chinese CO_2 emissions. Finally, Tamazian and Rao (2010) found that financial development reduces environmental degradation when it is accompanied by a robust institutional framework.

After this summary on the studies that support the view that financial openness can mitigate environmental degradation, it is time to move on to the other branch of the literature and describe the studies that support the view that financial openness has a detrimental effect on the environment (see Table 2).

There are several reasons for the achievement of such results. For example, Islam et al. (2013) found that financial openness increased the capital supply, and, consequently, reduced the credit price, which encouraged the purchase of appliances, autos, and homes, and stimulated the firms' and household's investment. This consequently led to an increase in the economic output, energy consumption from fossil sources, and CO_2 emissions. This conclusion is also supported by several authors who reached similar results, using different variables, time spans, samples, and methodologies, such as Koçak and Şarkgüneşi (2018), Jugurnath and Emrith (2018), Bekhet et al. (2016), Jamel (2017), Abbasi and Riaz (2016), Lau et al. (2014), Ren et al. (2014), and Shahbaz et al. (2013a).

Chang (2015), complemented the ideas of the authors cited above, confirming that financial openness can increase industrial productivity because it leads to new investments and an increase in the household's consumption (resulting from a cheaper market credit). All of these facts have a direct impact on the economic activity and, consequently, have an impact (increase) on both energy demand and environmental degradation.

Although the literature has used different samples, variables, and methodologies to explain the impact of financial liberalisation/financial development on environmental degradation, there are still some gaps which need to be filled. As an example, in this literature review, we see that the majority of the authors, except You et al. (2015), used the variable financial development index instead

Table 1 Authors who identify the negative impact on environmental degradation

Author(s)	Methodology	Time span	Countries/region	Impact
Saidi and Mbarek (2017)	Generalised method of moments (GMM) model	1990–2013	19 emerging countries	–
Abbasi and Riaz (2016)	ARDL model in the form of a UECM	1971–2011 and 1988–2011	Pakistan	–
Salahuddin et al. (2015)	Dynamic ordinary least squares (DOLS), fully modified ordinary least squares (FMOLS), and the dynamic fixed effect model (DFE)	1980–2012	Gulf Cooperation Council (GCC) countries	–
You et al. (2015)	Panel quantile model	1985–2005	68 countries	–
Ozturk and Acaravci (2013)	ARDL model and Granger causality	1960–2007	Turkey	–
Shahbaz et al. (2013b)	ARDL Bounds test model and Granger causality tests	1971–2011	Malaysia	–
Shahbaz et al. (2013c)	ARDL model in the form of a UECM	1965–2008	South Africa	–
Shahbaz et al. (2013c)	ARDL bounds testing model	1971–2011	China	–
Jalil and Feridun (2011)	ARDL model	1953–2006	China	–
Tamazian and Rao (2010)	GMM model	1993–2004	24 transition economies	–

Table 2 Authors who identify the positive impact on environmental degradation

Author(s)	Methodology	Time span	Countries/region	Impact
Koçak and Şarkgüneşi (2018)	DOLS model	1974–2013	Turkey	+
Jugurnath and Emrith (2018)	OLS model	2004–2014	Small Island Developing States (SIDS)	+
Bekhet et al. (2016)	ARDL model	1980–2011	GCC countries	+
Jamel (2017)	OLS model	1985–2014	40 European countries	+
Abbasi and Riaz (2016)	ARDL model	1971–2011 and 1988–2011	Pakistan	+
Chang (2015)	IPAT model	1999–2008	53 countries	+
Lau et al. (2014)	OLS model and Granger causality tests	1970–2008	Malaysia	+
Ren et al. (2014)	GMM model	2000–2010	China	+
Shahbaz et al. (2013a)	ARDL bounds testing model, VECM model, and Granger causality tests	1975Q1–2011Q4	Indonesia	+
Islam et al. (2013)	ARDL model	1971–2009	Malaysia	+

of the financial openness variable. The problem with this approach is that the variable financial openness generates more robust and statistically significant results than the financial development index. For this reason, we think that the use of this variable in this type of studies should be considered more. Moreover, we also think that the non-use of robustness tests in the previous studies, mainly in the ones that use the ARDL methodology, is a drawback that should also be taken into account. Another gap is that the authors only made use of the total energy consumption from fossil fuels in their estimations, forgetting the alternative energy sources and their impact on environmental degradation. Finally, there is a lack of studies focused on the Latin American and Caribbean countries specifically, with the authors focusing their studies mainly on regions such as Asia and Europe.

This article will try to fill the gaps that were previously described using a new approach which includes: (1) the use of renewable energy consumption, to identify the effect of alternative energy sources on environmental degradation; (2) the use of financial openness, instead of financial development index; (3) the inclusion of impulse dummies to test the robustness of the model; and (4) the use of the Latin America and the Caribbean region as the sample of our study, given that this region is not addressed in the literature.

Based on the literature review and the central question of this study, we developed the following two hypotheses:

Hypothesis 1: Financial openness increases environmental degradation, given that it encourages investment and consumption, and consequently the economic activity intensification. This intensification increases the consumption of both fossil fuels and natural resources, which leads to an increase in environmental degradation.

Hypothesis 2: Financial openness reduces environmental degradation, given that it encourages the investment and purchase of green technologies with high energy efficiency, thus leading to a reduction on energy demand and, consequently, on environmental degradation.

This literature review exhibited the most critical studies on the impacts of financial openness/development on environmental degradation and their respective conclusions, focusing primarily on the impact of financial openness on CO_2 emissions. The next section will present/explain the data and methodology that were used in this research.

3 Method and description of variables

This section is divided into two sub-sections: the first sub-section describes the methodology that was adopted in this study, while the second describes the data/variables that were used to accomplish our goals.

3.1 Method

In this study, we used the ARDL model in the form of a UECM to decompose the total effects of the variables into their short- and long-run components. This model was initially developed by Granger (1981) and Engle and Granger (1987) and improved by Johansen and Juselius (1990) with the introduction of cointegration techniques that overcame the difficulties in determining long-run relationships between series that are non-stationary, as well as reparametrising them into the error correction model (ECM) (Nkoro and Uko 2016). Moreover, this model is capable of producing consistent estimates for the long-run parameters that are asymptotically normally distributed.

Additionally, other authors, such as Pesaran et al. (2001), found that the ARDL model is robust to the presence of endogeneity among the variables, given that it is serial correlation free. Also, this model is more flexible than other models, such as the dynamic OLS (DOLS), the generalised method of moments (GMM), or the fully modified OLS (FMOLS). Moreover, the possibility of using the ARDL model as a dynamic fixed effects estimator has allowed the distinction between the short- and long-run Granger causalities between the variables (e.g. Menegaki et al. 2017; Fuinhas et al. 2017; Koengkan 2018). For all of these reasons, the ARDL model was the preferred methodology to carry out this research. Several authors who studied the nexus between financial openness and environmental degradation also chose to use this same methodology (e.g. Koengkan 2018; Bekhet et al. 2016; Abbasi and Riaz 2016; Boutabba 2014; Shahbaz et al. 2013a, c, d; Islam et al. 2013). The general ARDL model follows the specification of Eq. (1):

$$\begin{aligned}\Delta \mathrm{LCO}_{2\mathrm{it}} = \sigma_{0\mathrm{it}} &+ \sum_{t=0}^{k} \phi_{2\mathrm{it}} \Delta \mathrm{LKAOPEN}_{\mathrm{it}} + \sum_{t=0}^{k} \phi_{3\mathrm{it}} \Delta \mathrm{LGDP}_{\mathrm{it}} + \sum_{t=0}^{k} \phi_{4\mathrm{it}} \Delta \mathrm{LRENEWABLE}_{\mathrm{it}} \\ &+ \sum_{t=0}^{k} \phi_{5\mathrm{it}} \Delta \mathrm{LPRIMARY}_{\mathrm{it}} + \gamma_{1\mathrm{it}} \mathrm{LCO}_{2\mathrm{it}} + \gamma_{2\mathrm{it}} \Delta \mathrm{LKAOPEN}_{\mathrm{it}} + \gamma_{3\mathrm{it}} \mathrm{LGDP}_{\mathrm{it}} \\ &+ \gamma_{4\mathrm{it}} \mathrm{LRENEWABLE}_{\mathrm{it}} + \gamma_{5\mathrm{it}} \mathrm{LPRIMARY} + \omega_{1\mathrm{it}}, \end{aligned} \tag{1}$$

where ΔLCO_2 and LCO_2 are the dependent variables and LKAOPEN, LGDP, LRENEWABLE, LPRIMARY and ΔLKAOPEN, ΔLGDP, ΔLRENEWABLE, and ΔLPRIMARY are the independent variables. The prefixes ΔL and L denote first differences, and the natural logarithm of the variables, respectively. $\sigma_{0\mathrm{it}}$ represents the intercept, $\phi_{1\mathrm{it}} \ldots \phi_{5\mathrm{it}} \ldots \gamma_{1\mathrm{it}} \ldots \gamma_{5\mathrm{it}}$ represent the parameters of the variables, and $\omega_{1\mathrm{it}}$ represents the error term.

Before we proceed with the estimation, it is wise to verify the properties of the variables through the application of a set of preliminary tests, namely:

- Variance inflation factor (VIF) (Belsley et al. 1980) to check for the presence of multicollinearity among the variables. This test indicates the impact of multicollinearity on the estimated regression coefficients (e.g. O'Brien 2007).
- Cross-sectional dependence (CSD test) (Pesaran 2004) to check for the existence of cross-sectional dependence in the variables.

- Correlation test/matrix, which measures the statistical relationship between a pair of variables.
- Pesaran's CADF test to check for the existence of unit roots in the variables. This test has as the null hypothesis that the series are non-stationary I(1).
- Second-generation cointegration test of Westerlund (2007) to check for the presence of cointegration. The null hypothesis is no cointegration. The Westerlund cointegration test requires that all variables of the model be I(1) (Koengkan 2018; Fuinhas et al. 2017).
- Hausman specification test (Hausman 1978), which compares random effects (RE) with individual fixed effects (FE); this test has the null hypothesis that the best model is the random effects model.
- Mean group (MG) and pooled mean group (PMG) estimators were applied to check for the existence of parameter heterogeneity. The MG estimator calculates the coefficients of all individuals in the regressions for each cross. However, this estimator is inefficient in the presence of homogeneity (Pesaran et al. 1999). The PMG estimator makes restrictions among cross sections and limits the speed of adjustment. This estimator is more efficient than the MG estimator in the presence of parameter homogeneity and has already been used in the literature (e.g. Fuinhas et al. 2017).

Additionally, the best econometric practice strongly recommends employing the following specification tests:

- Modified Wald test (Greene 2002) to check for the existence of groupwise heteroskedasticity.
- Wooldridge test (Wooldridge 2002) to check for the existence of serial correlation.
- Pesaran test of cross-sectional independence (Pesaran 2007) to check for the existence of contemporaneous correlation among cross-sections.
- Breusch and Pagan Lagrangian multiplier test of independence (Breusch and Pagan 1980) to check whether the variances across individuals are correlated.

3.2 Material

To analyse the impact of financial openness on environmental degradation in the LAC region, we collected data from 1980 to 2014 for 21 countries, namely: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Trinidad and Tobago, Uruguay, and Venezuela. The variables chosen to conduct this analysis were:

- Total CO_2 emissions (CO_2) from the burning of fossil fuels and the manufacture of cement. These include carbon dioxide produced during consumption of solid, liquid, and gas fuels, and gas flaring. These data are available at the World Bank Data (WBD) (2018) and represents our proxy for environmental degradation.

- Financial openness index (KAOPEN), which measures a country's degree of capital account openness, available at the Chinn-Ito Index (2017). This indicator 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).
- Gross domestic production (GDP), in constant local currency units (LCU), available at the World Bank Data (WBD) (2018).
- Renewable energy consumption (RENEWABLE), in Billion kWh, from wind, hydro, photovoltaic, wave, waste, and biomass, available at the IEA (2018).
- Primary energy consumption (PRIMARY), in Billion kWh, from oil, gas, coal, wind, hydro, photovoltaic, wave, waste, and biomass, also available at the IEA (2018).

These variables were chosen because the LAC region has registered a rapid economic growth in the last 40 years, jointly with a fast increase in its energy consumption and a prompt evolution in its economic, financial, and trade openness levels. All of these economic and social structure changes have had a significant impact on the LAC region environment, with the increase in its air and water pollution, in its deforestation, and its depletion of natural resources. These circumstances make it easy to justify the choice of this region as the sample of this study. Table 3 presents the description of the variables and their respective summary statistics.

The variables LCO_2, LGDP, LRENEWABLE, and LPRIMARY were all transformed into per capita values. Also, we should also refer that the variable LKAOPEN contained some zero values (which could lead to some estimation problems) and, for that reason, we had to add a constant, in this case (1), to the raw financial openness index. This method does not compromise the estimation and allows to dodge the problems that could arise from the fact that the variable contains zero values. The option to use the GDP in constant local currency units (LCU), instead of constant US dollars, allows attenuating the influence of the inflation and the changes in the exchange rates (Koengkan 2018). The GDP in constant local currency units (LCU) was already used by several authors who focused their studies on the Latin American region (e.g. Koengkan 2018; Fuinhas et al. 2017). We should also mention that the use of GDP in constant US dollars was previously tested, but the results were far from satisfactory. Finally, it is essential to state that the smaller number of observations in the variable LGDP (733) is due to the unavailability of data on this variable for Venezuela and Porto Rico in 2014. This situation is the result of a severe economic and social crisis that Venezuela has been suffering a severe economic and political crisis and Puerto Rico has suffered a severe fiscal crisis, which made it impossible for their central banks to release data on the GDP of both countries in 2014. In the next section, we will show the results from both the preliminary and specification tests, as well as from the ARDL estimation (with and without accounting for shocks) and also the discussion of results.

Table 3 Description of variables and summary statistics

Variables	Description	Descriptive statistics				
		Obs.	Mean	Std. Dev.	Min	Max
LCO_2	Logarithm of total CO_2 emissions from energy consumption	735	− 13.1717	0.9578	− 14.8670	− 10.1318
LKAOPEN	Logarithm of 1 + financial openness	735	0.3956	0.2519	0.0000	0.6931
LGDP	Logarithm of gross domestic production (GDP)	733	10.5893	2.7029	6.7691	16.1938
LRENEWABLE	Logarithm of renewable energy consumption	735	− 14.6771	1.4126	− 18.4883	− 11.4340
LPRIMARY	Logarithm of primary energy consumption	735	− 17.0991	0.8838	− 18.8181	− 14.1570

Obs. the number of observations, *Std. Dev*. the standard deviation, *Min. and Max*. minimum and maximum, respectively, (*L*) variables in natural logarithms

4 Empirical results and discussion

First, to check for the presence of collinearity, we computed the correlation matrix with the variables in levels and first differences. In Table 4, we can see the results from this test.

Looking at the results from the previous table (Table 2), we see that there is one value that may need some further explanation: the variables LPRIMARY and LCO_2 present a correlation slightly above 90%. Some studies (e.g. Jaforullah and King 2017; Burnett et al. 2013; Itkonen 2012) have signalled some drawbacks that could derive from the fact that these two variables are strongly related in their construction—the variable CO_2 emissions are constructed based on the emissions from different energy sources. However, this should not be a deterrent to the use of primary energy in the explanation of this same variable. Moreover, this does not yield any econometric problem, given that this high correlation is registered between the dependent variable and an independent one.

The inclusion of primary energy in the estimation can contribute to capturing the effects that the other variables may exert on primary energy consumption, and consequently on the CO_2 emissions. The high correlation value between these two variables is mainly explained by the fact that primary energy (composed of several energy sources) can influence to a great deal the amount of CO_2 emissions produced by these countries. In the Latin America and Caribbean region, there is a considerable share of renewable energy sources in the energy matrix, mostly due to its abundance in natural resources, and therefore the consumption of primary energy from fossil fuels varies because of the existence of a substitution effect between fossil and renewable energy sources. This is why the correlation between primary energy and CO_2 emissions is less than 100%.

Table 4 Matrices of correlations

Variables	LCO_2	LKAOPEN	LGDP	LRENEWABLE	LPRIMARY
LCO_2	1.0000				
LKAOPEN	0.2990***	1.0000			
LGDP	− 0.0887**	− 0.1592***	1.0000		
LRENEWABLE	− 0.3245***	− 0.1121***	0.2757***	1.0000	
LPRIMARY	0.9067***	0.2894***	0.0821**	− 0.0480	1.0000
Variables	ΔLCO_2	ΔLKAOPEN	ΔLGDP	ΔLRENEWABLE	ΔLPRIMARY
ΔLCO_2	1.0000				
ΔLKAOPEN	0.0918**	1.0000			
ΔLGDP	0.2375***	0.1451***	1.0000		
ΔLRENEWABLE	− 0.1023***	0.0167	0.0093	1.000	
ΔLPRIMARY	0.5152***	0.0423	0.1993***	0.2879***	1.0000

***,**Statistically significant at 1% and 5% level, respectively. The Stata command *pwcorr* was used; (L and Δ) denote variables in natural logarithms and first differences of logarithms, respectively

The next step of this analysis was to inquire about the presence of multicollinearity and the existence of cross-sectional dependence in the variables, through the use of the VIF test and of the CSD test, respectively. In Table 5, we can observe the outcomes of both tests.

Multicollinearity seems not to be a concern for the estimation given that the "mean" VIFs of the variables in levels and first differences are below the generally accepted benchmark of 10. Regarding the results from the CD test, we see that the presence of cross-sectional dependence was detected in all variables, except the variables LKAOPEN and ΔLKAOPEN, to which the test could not be applied (both variables contain zero values). The presence of cross-sectional dependence implies that the second-generation unit root tests are the most appropriate to access the stationarity of the variables. In this sense, Table 6 shows the outcomes of Pesaran's CADF unit root test.

The results from Pesaran's CADF test unit root test suggest that the variables LCO_2, LRENEWABLE, and LPRIMARY, with and without "TREND" are I(0), while the variables LKAOPEN and LGDP are I(1). Regarding the variables in first differences, they all seem to be I(0). The non-stationarity of some of the variables is expected, leading to a potential "spurious correlation" problem. Therefore, it is recommended to apply the second-generation cointegration test of Westerlund (2007) to check the cointegration between the variables which are not stationary. The results from this test can be seen in Table 7.

The results reject the hypothesis of cointegration, as it was expected, suggesting the use of an econometric technique less stringent concerning the variables integration order, i.e. the ARDL model (e.g. among others, Koengkan 2018). After all the information that has been obtained, the next step was to determine if the panel has random or fixed effects. For that purpose, the Hausman test was computed and its results can be seen in Table 8.

Table 5 VIF and CSD tests

Variables	VIF	1/VIF	CD test	*p* value	Corr	Abs (corr)
LCO_2	n.a.		46.24	0.000***	0.540	0.569
LKAOPEN	1.14	0.8795	n.a.			
LGDP	1.13	0.8877	64.98	0.000***	0.759	0.763
LRENEWABLE	1.09	0.9170	31.38	0.000***	0.367	0.433
LPRIMARY	1.12	0.8955	51.74	0.000***	0.605	0.706
Mean VIF	1.12					
ΔLCO_2	n.a.		6.73	0.000***	0.080	0.171
ΔLKAOPEN	1.02	0.9786	n.a.			
ΔLGDP	1.07	0.9389	24.39	0.000***	0.289	0.309
ΔLRENEWABLE	1.09	0.9145	2.37	0.018***	0.028	0.171
ΔLPRIMARY	1.14	0.8783	9.15	0.000***	0.108	0.186
Mean VIF	1.08					

***Statistically significant at 1% level; *n.a* not available. The Stata command *xtcd* was used; (L and Δ) denote variables in natural logarithms and first differences of logarithms respectively

Table 6 Unit roots test

Variables	Pesaran's CADF test—*Z*(*t*-bar)	
	Without trend	With trend
LCO_2	− 5.275***	− 2.710***
LKAOPEN	− 1.208	0.102
LGDP	0.746	− 0.590
LRENEWABLE	− 3.960***	− 5.298***
LPRIMARY	− 4.953***	− 1.904**
ΔLCO_2	− 13.582***	− 11.661***
ΔLKAOPEN	− 9.085***	− 6.990***
ΔLGDP	− 9.653***	− 8.497***
ΔLRENEWABLE	− 14.606***	− 13.217***
ΔLPRIMARY	− 12.919***	− 11.160***

***,**Statistically significant at 1% and 5% level, respectively; Pesaran's CADF test having H_0: series are I(1). The Stata command *pescadf* was used; (L and Δ) denote variables in natural logarithms and first differences of logarithms, respectively

Table 7 Westerlund test

Westerlund test (with constant)		
Statistics	Value	*p* value robust
Gt	− 1.657	0.427
Ga	− 5.361	0.673
Pt	− 7.190	0.240
Pt	− 5.359	0.160

Bootstrapping regression with 300 reps. H_0 no cointegration; H_1 Gt and Ga test the cointegration for each country individually and Pt and Pa test the cointegration of the panel as a whole; the Stata command *xtwest* was used

The results from the Hausman test indicated that the FE specification is the most suitable for the estimation [Chi^2 (9) = 80.40 statistically significant at 1%]. However, to inquire about the models' heterogeneity, the MG and PMG estimators were used in conjunction with the FE estimator, with Table 9 showing the outcomes of these three specifications.

From the information presented in the previous and following tables (Tables 8, 9), we see that the FE estimator is the most suitable one. This means that the panel is homogeneous and that the variables share common shocks among the countries from the sample (Table 10).

To confirm the statistical significance from the FE estimator parameters, we had to compute a battery of specification tests, namely: (1) the modified Wald test for groupwise heteroskedasticity; (2) the Wooldridge test; (3) the Pesaran test; and (4) the Breusch and Pagan Lagrangian multiplier test. Table 11 shows the results of the previously stated tests.

Table 8 Hausman test

Variables	(b) Fixed	(B) Random	(b–B) Difference	Sqrt(diag(V_b–V–B)) S.E.
ΔLKAOPEN	0.0785	0.0573	0.0211	0.0082
ΔLGDP	0.2769	0.2945	– 0.0175	0.0154
ΔLRENEWABLE	– 0.1274	– 0.1298	0.0023	0.0067
ΔLPRIMARY	0.6414	0.6085	0.0328	0.0130
LCO_2	– 0.2174	– 0.0324	– 0.1850	0.0209
LKAOPEN	0.0339	– 0.0021	0.0360	0.0141
LGDP	0.0617	– 0.0023	0.0640	0.0211
LRENEWABLE	– 0.0295	– 0.0062	– 0.0232	0.0103
LPRIMARY	0.1409	0.0310	0.1098	0.0211
CONSTANT	– 1.5537	0.0395	– 1.5932	0.4404
Chi^2 (9)	80.40 ***			

***Statistically significant at 1% level; (L and Δ) denote variables in natural logarithms and first differences of logarithms, respectively

Table 9 Heterogeneous estimators

Independent variables	Dependent variables (ΔLCO_2)		
	MG	PMG	FE
Constant	0.7896	0.9998***	– 1.5538***
ΔLKAOPEN	0.0068	0.0275	0.0785**
ΔLGDP	0.2617***	0.2311***	0.2769***
ΔLRENEWABLE	– 0.1961***	– 0.2031***	– 0.1274***
ΔLPRIMARY	0.9047***	0.9031***	0.6415***
ECM	– 0.7362***	– 0.2324***	– 0.2175***
LKAOPEN	0.0241	– 0.0645**	0.1559*
LGDP	0.0968	0.0694**	0.2839***
LRENEWABLE	– 0.1288	– 0.4658***	– 0.1357***
LPRIMARY	0.9360***	1.4486***	0.6480***

***,**,*Statistically significant at 1, 5, and 10% level, respectively; The ECM denotes the coefficient of the variable LCO_2, lagged once; the long-run parameters are computed elasticities. The Stata command *xtpmg* was used; (L and Δ) denote variables in natural logarithms and first differences of logarithms, respectively

Table 10 Hausman test

MG vs. PMG	PMG vs. FE	MG vs. FE
Chi^2 (9) = – 661.21	Chi^2 (9) = – 130.36	Chi^2 (9) = 175.73***

***,**,*Statistically significant at 1, 5, and 10% level, respectively; Hausman results for H_0: difference in coefficients not systematic; the Stata commands *xtpmg*, and Hausman (with the options, sigmamore alleqs constant) were used

Table 11 Specification tests

Statistics	Modified Wald test	Wooldridge test	Pesaran test	Breusch and Pagan Lagrangian multiplier test
	Chi^2 (21) = 921.09***	F (1,20) = 333.537***	6.207***	n.a.

***Statistically significant at 1% level; results for H_0 of modified Wald test: sigma$(i)^2$ = sigma^2 for all i; results for H_0 of Wooldridge test: no first-order autocorrelation; results for H_0 of Pesaran's test: residuals are not correlated

The specification tests pointed to the existence of groupwise heteroskedasticity, serial correlation, and cross-sectional dependence in the model. Given this fact, the use of the Driscoll and Kraay (1998) estimator (FE D.–K.) seems to be a most suitable option, because it is capable of producing standard errors robust to the presence of such phenomena (e.g. Santiago et al. 2018). Before we proceed, we should stress that the Breusch and Pagan Lagrangian multiplier test could not be carried out because the correlation matrix of residuals was singular (number of countries is higher than the number of years). The results from the FE e, FE robust, and FE D.–K. estimators are shown in Table 12.

The results from Table 10 do not show all the information needed to reach robust conclusions. The long-run elasticities have to be calculated dividing the coefficients

Table 12 Estimation results

Independent variables	Dependent variables (ΔLCO_2)		
	FE	FE robust	FE D.-K.
Constant	− 1.5538***	*	***
ΔLKAOPEN	0.0785**	**	***
ΔLGDP	0.2769***	***	***
ΔLRENEWABLE	− 0.1274***	**	***
ΔLPRIMARY	0.6415***	***	***
LCO_2	− 0.2175***	***	**
LKAOPEN	0.0339*		**
LGDP	0.0617***	**	****
LRENEWABLE	− 0.0295***		*
LPRIMARY	0.1409***	***	*
	Statistics		
N	712	712	712
R^2	0.4327	0.4327	n.a
R^2_a	0.4086	0.4254	n.a
F	57.7970	114.4318	55.3810

***,**,*Statistically significant at 1, 5, and 10% level, respectively; *n.a.* not available; the Stata commands *xtreg*, and *xtscc* were used; (L and Δ) denote variables in natural logarithms and first differences of logarithms, respectively of the variables by the coefficient of LCO_2, both lagged once, and multiplying this ratio by (− 1). In Table 13, the short-run impacts and the long-run elasticities are presented, as well as the model speed of adjustment (ECM).

From Table 13, we see that the long-run elasticities and the short-run impacts from the FE, FE robust, and FE D.–K. estimators were all statistically significant, meaning that all explanatory variables seem to have had direct effects on the dependent variable in both the short and long run. Additionally, the negative and statistically significant ECM coefficient pointed to the presence of cointegration/long memory between the variables.

As it is known, the majority of the LAC countries suffer from huge economic shocks that may distort the results from the studies and lead to false conclusions. To assess the robustness of the previous estimation, a set of dummy variables was added to the model to control for the shocks that occurred in some of the LAC countries during the years under analysis. These dummies were: IDPANAMA1981 (Panama, year 1981), IDPANAMA1982 (Panama, year 1982), IDPANAMA1983 (Panama, year 1983), IDPANAMA1984 (Panama, year 1984), and IDPANAMA1985 (Panama, year 1985). The inclusion of dummies to control for shocks has already been tested in the literature (see, e.g. Koengkan 2018; Fuinhas et al. 2017). These dummies were included in all three specifications. Table 14 shows the results, i.e. the short-run impacts, the long-run elasticities, and the ECM, from the FE, FE Robust, and FE D.–K. estimators after the inclusion of the dummy variables.

The statistical significance of the dummy variables that were included in the model seems to show that their inclusion is, indeed, a good practice. The next section will present a more profound discussion of the results from the model with

Table 13 Elasticities, short-run impacts, and speed of adjustment

Independent variables	Dependent variables (ΔLCO_2)		
	FE	FE robust	FE D.-K.
Constant	− 1.5538***	**	**
Short run			
ΔLKAOPEN	0.0785**	**	**
ΔLGDP	0.2769***	**	***
ΔLRENEWABLE	− 0.1274***	**	***
ΔLPRIMARY	0.6415***	***	***
Long run			
LKAOPEN (− 1)	0.1559**	*	***
LGDP (− 1)	0.2839***	***	**
LRENEWABLE (− 1)	− 0.1357***	**	***
LPRIMARY (− 1)	0.6480***	***	***
Speed of adjustment			
ECM	− 0.2175***	***	***

***,**,*Statistically significant at 1, 5, and 10% level, respectively; The ECM denotes the coefficient of the variable LCO_2, lagged once; (L and Δ) denote variables in natural logarithms and first differences of logarithms, respectively

Table 14 Elasticities, short-run impacts, impacts, and adjustment speed (with shocks)

Independent variables	Dependent variables (ΔLCO_2)		
	FE	FE Robust	FE D.-K.
Constant	– 1.6691***		***
Shocks			
IDPANAMA1981	– 0.3216***	***	***
IDPANAMA1982	– 0.4063***	***	***
IDPANAMA1983	– 0.3060***	**	**
IDPANAMA1984	– 0.3208***	**	**
IDPANAMA1985	– 0.5490***	***	***
Short run			
ΔLKAOPEN	0.0872***	**	**
ΔLGDP	0.2685***	**	***
ΔLRENEWABLE	– 0.1329***	**	***
ΔLPRIMARY	0.6586***	***	***
Long run			
LKAOPEN (– 1)	0.1508***	**	***
LGDP (– 1)	0.1829***	**	***
LRENEWABLE (– 1)	– 0.2081***	***	***
LPRIMARY (– 1)	0.7752***	***	***
Speed of adjustment			
ECM	– 0.3367***	**	***

***,**Statistically significant at 1%, and 5% level, respectively; the ECM denotes the coefficient of the variable LCO_2, lagged once; (L and Δ) denote variables in natural logarithms and first differences of logarithms, respectively

and without accounting for shocks, jointly with some explanations for the obtained outcomes.

The impact of financial openness on environmental degradation, which in this study is represented by CO_2 emissions, was analysed for 21 LAC countries. The results of the preliminary tests pointed to the existence of a low correlation degree between the variables, except the correlation between primary energy consumption and CO_2 emissions, both in the levels around 90% (see Table 4). Primary energy is composed of different energy sources (renewable and fossil) which, consequently, produce different amounts of CO_2 emissions. However, in the LAC countries, the share of renewables in the primary energy mix is enormous and a substitution effect can be observed between this type of energy and the energy produced by non-renewable sources. This substitution occurs in periods of drought, when the hydroelectric reservoirs are empty, or when the production of renewable sources cannot satisfy the demand. To cope with this problem, these countries resort to thermoelectric generation.

Still, in the preliminary analysis, we also concluded that multicollinearity was not a problem for the estimation and that cross-sectional dependence was present in all variables except financial openness in levels and first differences (see Table 5). Also, by the Pesaran's CADF test and the Westerlund test, we confirmed the presence of unit roots in the variables in levels (see Table 6) and the hypothesis of no cointegration among the variables LKAOPEN and LGDP (see Table 7), respectively. Furthermore, the Hausman tests between the RE and FE specifications (see Table 6), and between the MG, PMG, and FE specifications (see Table 10), indicated that the FE specification was the most suitable for this analysis and that the panel was homogenous, i.e. the variables shared common shocks in the selected panel of countries.

Additionally, the specification tests made before the estimation pointed to the presence of heteroskedasticity, serial correlation, and cross-sectional dependence in the model (see Table 11). These results are in line with the ones from other authors who have studied the same group of countries (e.g. Santiago et al. 2018; Fuinhas et al. 2017; Koengkan 2017).

After all this process, we proceed with the model estimation, using appropriate techniques to deal with the characteristics found. The results from Table 13 indicated that financial openness was able to increase the CO_2 emissions of the LAC countries in both the short and long run. These results are in line with the ones from several previous studies which were focused on the investigation of this same nexus (e.g. Jamel 2017; Bekhet et al. 2016; Abbasi and Riaz 2016; Chang 2015; Boutabba 2014; Ren et al. 2014; Lau et al. 2014; Islam et al. 2013; Shahbaz et al. 2013d; Blanco et al. 2012).

The reasons for the positive impact of financial openness on these countries' CO_2 emissions are probably related to the increase of domestic credit in the private sector, triggered by the region's financial openness intensification, which raised both the economic activity and the energy demand of the LAC countries and, consequently, their environmental degradation (Chang 2015). This is also the view of Islam et al. (2013) and Shahbaz et al. (2013d), which state that financial openness increases economic activity, which, in its turn, increases energy demand, mainly due to the cheaper credit that facilitates the purchase of cars, homes, and appliances. In their view, all of these facts produce a chain effect that leads to an increase of CO_2 emissions. In the same logic, Blanco et al. (2012) also stress that FDI development promotes the pollution-intensive industry growth, thus leading to increased CO_2 emissions. We can summarise the impact of financial openness on carbon dioxide emissions in a scheme shown in Fig. 1.

The results from Table 11 also pointed out that the economic growth and primary energy consumption are drivers of CO_2 emissions, with both variables showing a positive impact on the LAC countries' emissions. Regarding the positive impact of the economic growth on CO_2 emissions, we see that this result is also confirmed by several authors who have identified this same effect on the LAC countries (e.g. Koengkan 2018; Fuinhas et al. 2017; Zilio and Recalde 2011; Dasgupta et al. 2001). This result can be mainly attributed to structural economic changes, such as the transition from rural to industrial activities (Zilio and Recalde 2011) and/or to the increase in trade flows (Dasgupta et al. 2001). The increase in energy demand, which we previously talked about, can also be a channel through which economic growth can affect the environment. With regard to primary energy consumption,

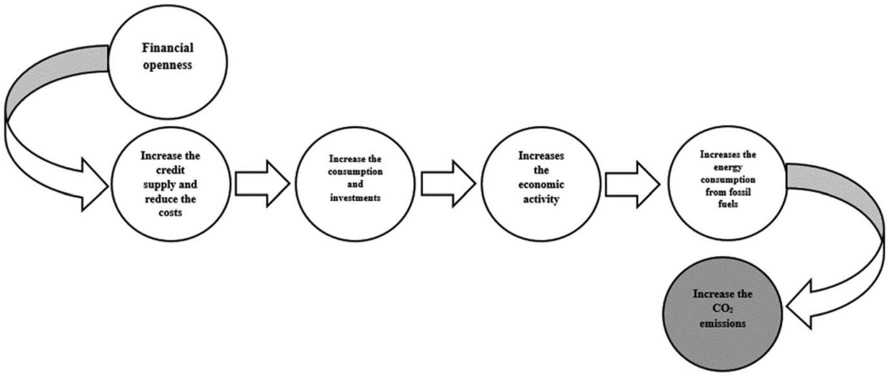

Fig. 1 Summary of the impact of financial openness on CO_2 emissions

we see that our findings confirm those from Fuinhas et al. (2017), and Behera and Dash (2017). This outcome can be due to the dependency of the LAC region on fossil fuels, with many of its countries being significant fossils fuel producers, such as Argentina, Brazil, Colombia, Ecuador, Mexico Peru, and Venezuela, or major fossil fuel importers, such as Chile, and Central America and Caribbean countries (Fuinhas et al. 2017). Additionally, Behera and Dash (2017) state that when fossil fuels are incorporated into the overall primary energy consumption, short- and long-run relationships between primary energy consumption and CO_2 emissions can be expected in both high- and low-income countries.

In contrast, renewable energy consumption seems to have reduced these countries' emissions both in the short and long run. This conclusion is in line with several authors who have studied the impact of renewable energy on environmental degradation (e.g. Koengkan 2018; Fuinhas et al. 2017; Zoundi 2017; Gill et al. 2017). This effect can be mainly attributed to renewable energy policies, which supported the replacement of fossil fuels with renewable sources in the LAC countries' energy production (Fuinhas et al. 2017). Moreover, previous literature has pointed that the use of renewable energy contributes to the improvement of air quality, given that the increase of 1% in renewable energy consumption seems to reduce CO_2 emissions in 0.13% (Zoundi 2017).

Moreover, the ECM parameter of the ARDL model has a negative sign and is statistically significant at 1% (see Table 13), which means that there is a Granger causality running from the statistically significant variable to the CO_2 emissions. Indeed, the UECM in an ARDL model allows to break down the total causalities of all variables into their short- and long-run components, allowing to take similar conclusions to the ones from the Granger causality test (e.g. Koengkan 2018; Jouini 2015; Mehrara 2007). However, the inference on the causalities between the variables is not the purpose of this paper.

To test the robustness of the model, a set of dummy variables were introduced to control for the shocks (peaks and breaks of significant magnitude) that occurred in some LAC countries and which were identified through the residual's analysis. As it is widely known, the LAC region suffered from several social and economic crises during the 1980s, 1990s, and 2000s, and so it becomes of particular interest to make this kind of analysis when the authors centre their studies on this region.

An example of such a crisis is the one that occurred in Panama during the 1980s. The economy of Panama grew 15.4% in 1980, 4.2% in 1981, and 5.6% in 1982. However, due to the severe recession in the Latin American region, the economy of Panama only grew 0.4% in 1983 and declined − 0.4% in 1984. This recession coincided with the rise of General Manuel Noriega to power which, consequently, brought social instability to the country. In 1985, Panama had an economic recovery, with its GDP growing 4.1% in that same year (Meditz and Hanratty 1989, pp. 79–82). According to to this historical analysis and with the residual analysis, dummy variables were added to cope with these shocks, namely: IDPANAMA1981 (Panama, year 1981), IDPANAMA1982 (Panama, year 1982), IDPANAMA1983 (Panama, year 1983), IDPANAMA1984 (Panama), and IDPANAMA1985 (Panama, year 1985). These dummies were incorporated into the FE, FE Robust, and FE D.–K., models (see Table 14). The dummy variables were all statistically significant at 1%, which reinforced the reason for its use. If one compares the results from Table 13 with the ones from Table 14, we see that the ECM of the model that accounts for the shocks (with dummies) is higher than the one that does not account for them. The model proved to be robust to the inclusion of shocks, with the impacts of the variables maintaining their previous signals and their statistical significance, with an improvement (from 5 to 1%) in the case of the financial openness statistical significance. In the next section, we will present the conclusions and the policy implications of this study.

5 Conclusion and policy implications

In this study, we applied the UECM form of the ARDL model to analyse the short- and long-run impacts of financial openness on the environmental degradation of a group of Latin America and Caribbean countries between 1980 and 2014. The results from the estimations confirmed the hypothesis that financial openness increased CO_2 emissions (environmental degradation) in these countries. Both economic growth and primary energy consumption also demonstrated to have had an enhancing effect on the emissions of LAC countries. In contrast, renewable energy consumption seems to have contributed to the decrease in CO_2 emissions, i.e. it was able to reduce these countries' environmental degradation. All the impacts were verified in the short and long run. The robustness analysis, through the correction of shocks, confirmed the previous outcomes.

A possible explanation for the effect of financial openness on environmental degradation is related with the increase in domestic credit to the private sector that positively stimulated the LAC countries' economic growth, as also their energy use and, consequently, led to an increase in their CO_2 emissions. In other words, financial openness had an indirect effect on environmental degradation. Indeed, due to an excessive offer of cheaper credit (provided by the financial openness intensification), the economic activity of these group of countries accelerated, leading to a rise in their energy and natural resources consumption and, subsequently, to an increase in the region's environmental degradation (via CO_2 emission increase).

These empirical results suggest that this region needs to put more effort in the development of energy policies that contribute to the increase of renewable energy consumption and, inversely, reduce fossil fuel consumption, either by their households or by their industries. We also think that the governments from the LAC should develop subsidy programmes to encourage consumers to purchase appliances with higher energy efficiency and, in this way, reduce their overall energy consumption. Additionally, regarding financial openness, we think that it can be combined with the reduction of environmental degradation, but only if the governments agree to a set of financial reforms to foster sustainable development and promote renewable energy projects. Given the mistakes that were committed in the past, the policymakers from the LAC region should also think about the possibility of integrating measures linked to CO_2 emission regulation in their growth strategies.

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References

Abbasi F, Riaz K (2016) CO_2 emissions and financial development in an emerging economy: an augmented VAR approach. Energy Policy 90:102–114. https://doi.org/10.1016/j.enpol.2015.12.017

Aizenman J (2005) Financial liberalizations in Latin America in the 1990s: a reassessment. NBER working paper series, no. 11145, pp 1–30

Balza LH, Espinasa R, Serebrisky T (2016) Lights on? Energy needs in Latin America and the Caribbean to 2040. Inter-American Development Bank, pp 1–39

Behera SR, Dash DP (2017) The effect of urbanisation, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. Renew Sustain Energy Rev 70:96–106. https://doi.org/10.1016/j.rser.2016.11.201

Bekhet HA, Matar A, Yasmin T (2016) CO_2 emissions, energy consumption, economic growth, and financial development in GCC countries: dynamic simultaneous equation models. Renew Sustain Energy Rev 70:117–132. https://doi.org/10.1016/j.rser.2016.11.089

Belsley DA, Kuh E, Welsch ER (1980) Regression diagnostics: identifying influential data and sources of collinearity. Wiley, New York

Bhattarai M, Hammig M (2001) Institutions and the environmental Kuznets curve for deforestation: a crosscountry analysis for Latin America, Africa, and Asia. World Dev 29(6):995–1010. https://doi.org/10.1016/S0305-750X(01)00019-5

Blanco L, Gonzalez F, Ruiz I (2012) The impact of FDI on CO_2 emissions in Latin America. Oxford Dev Stud 41(1):104–121. https://doi.org/10.1080/13600818.2012.732055

Boden TA, Marland G, Andres RJ (2011) Global, regional, and national fossil-fuel CO_2 emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge. https://doi.org/10.3334/CDIAC/00001_V2011

Boutabba MA (2014) The impact of financial development, income, energy and trade on carbon emissions: evidence from the Indian economy. Econ Model 40:33–41. https://doi.org/10.1016/j.econmod.2014.03.005

Breusch TS, Pagan AR (1980) The Lagrange multiplier test and its applications to model specification in econometrics. Rev Econ Stud 47(1):239–253

Burnett JW, Bergstrom JC, Wetzstein ME (2013) Carbon dioxide emissions and economic growth in the US. J Policy Model 35(6):1014–1028. https://doi.org/10.1016/j.jpolmod.2013.08.001

Chang S-C (2015) Effects of financial developments and income on energy consumption. Int Rev Econ Financ 35:28–44. https://doi.org/10.1016/j.iref.2014.08.011
Chinn MD, Ito H (2008) A new measure of financial openness. J Comp Policy Anal 10(3):309–322. https://doi.org/10.1080/13876980802231123
Dasgupta S, Laplante B, Maningi N (2001) Pollution and capital market in developing countries. J Environ Econ Manag 42(3):310–335. https://doi.org/10.1006/jeem.2000.1161
Driscoll JC, Kraay AC (1998) Consistent covariance matrix estimation with spatially dependent panel data. Econ Syst Res 10(4):307–324
Engle R, Granger G (1987) Cointegration and error correction: representation. Estim Test Econom 55:251–276
Fuinhas JA, Marques AC, Koengkan M (2017) Are renewable energy policies upsetting carbon dioxide emissions? The case of Latin America countries. Environ Sci Pollut Res 24(17):15044–15054. https://doi.org/10.1007/s11356-017-9109-z
Gill AR, Viswanathan KK, Hassan S (2017) A test of environmental Kuznets curve (EKC) for carbon emission and potential of renewable energy to reduce greenhouses gases (GHG) in Malaysia. Environ Dev Sustain. https://doi.org/10.1007/s10668-017-9929-5
Granger CWJ (1981) Some properties of time series data and their use in econometric model specification. J Econom 28:121–130
Greene W (2002) Econometric analysis. Prentice-Hall, Upper Saddle River
Hausman JA (1978) Specification tests in econometrics. Econometrica 46(6):1251–1271. http://links.jstor.org/sici?sici=0012-9682%2819781…O%3B2-X&origin=repec
International Energy Administration (IEA) (2018). https://www.iea.org/statistics/
Islam F, Shahbaz M, Ahmed AU, Alam MdM (2013) Financial development and energy consumption nexus in Malaysia: a multivariate time series analysis. Econ Model 30:435–441. https://doi.org/10.1016/j.econmod.2012.09.033
Itkonen JVA (2012) Problems estimating the carbon Kuznets curve. Energy 39(1):274–280. https://doi.org/10.1016/j.energy.2012.01.018
Jaforullah M, King A (2017) The econometric consequences of an energy consumption variable in a model of CO_2 emissions. Energy Econ 63:84–91. https://doi.org/10.1016/j.eneco.2017.01.025
Jalil A, Feridun M (2011) The impact of growth, energy and financial development on the environment in China: a cointegration analysis. Energy Econ 33(2):284–291. https://doi.org/10.1016/j.eneco.2010.10.003
Jamel L (2017) The nexus between economic growth, financial development, trade openness, and CO_2 emissions in European countries. J Cogent Econ Financ 5(1):1–25. https://doi.org/10.1080/23322039.2017.1341456
Johansen J, Juselius K (1990) Maximum likelihood estimation and inference on cointegration-with applications to the demand for money. Oxford Bull Econ Stat 52(2):169–210
Jouini J (2015) Economic growth and remittances in Tunisia: bi-directional causal links. J Policy Model 37(2):355–373. https://doi.org/10.1016/j.jpolmod.2015.01.015
Jugurnath B, Emrith A (2018) Impact of foreign direct investment on environment degradation: evidence from SIDS countries. J Dev Areas 52(2):13–26. https://doi.org/10.1353/jda.2018.0019
Koçak E, Şarkgüneşi A (2018) The impact of foreign direct investment on CO_2 emissions in Turkey: new evidence from cointegration and bootstrap causality analysis. Environ Sci Pollut Res 25(1):790–804. https://doi.org/10.1007/s11356-017-0468-2
Koengkan M (2017) Is the globalization influencing the primary energy consumption? The case of Latin America and the Caribbean countries. Cadernos UniFOA, Volta Redonda, 12(33):59–69 **(ISSN: 1809-9475)**
Koengkan M (2018) The decline of environmental degradation by renewable energy consumption in the MERCOSUR countries: an approach with ARDL modeling. Environ Syst Decis. https://doi.org/10.1007/s10669-018-9671-z
La Torre A, Ize A, Schmukler SL (2012) Financial development in Latin America and the Caribbean: the road ahead. World Bank Latin American and Caribbean studies, no. 65744, pp 1–278
Lau L-S, Choong C-H, Eng Y-K (2014) Investigation of the environmental Kuznets curve for carbon emissions in Malaysia: do foreign direct investment and trade matter? Energy Policy 68:490–497. https://doi.org/10.1016/j.enpol.2014.01.002
Meditz SW, Hanratty DM (1989) Panama: a country study. Washington, D.C.: Federal Research Division, Library of Congress: For sale by the Supt. of Docs., US G.P.O. https://www.loc.gov/resource/frdcstdy.panamacountrystu00medi/?sp=28

Mehrara M (2007) Energy consumption and economic growth: the case of oil exporting countries. Energy Policy 35(5):2939–2945. https://doi.org/10.1016/j.enpol.2006.10.018

Menegaki AN, Marques AC, Fuinhas JA (2017) Redefining the energy-growth nexus with an index for sustainable economic welfare in Europe. Energy 141:1254–1268. https://doi.org/10.1016/j.energy.2017.09.056

Nkoro E, Uko AK (2016) Autoregressive Distributed Lag (ARDL) cointegration technique: application and interpretation. J Stat Econom Methods 5(4):63–91 **(ISSN: 1792-6602)**

O'Brien RM (2007) A caution regarding rules of thumb for variance inflation factors. Qual Quant 41(5):673–690

Ozturk I, Acaravci A (2013) The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Econ 36:262–267. https://doi.org/10.1016/j.eneco.2012.08.025

Pesaran MH (2004) General diagnostic tests for cross section dependence in panels. The University of Cambridge, Faculty of Economics. Cambridge Working Papers in Economics, no. 0435. http://www.econ.cam.ac.uk/research/repec/cam/pdf/cwpe0435.pdf. Accessed 3 Sept 2018

Pesaran MH (2007) A simple panel unit root test in the presence of cross-section dependence. J Appl Econom 22(2):256–312. https://doi.org/10.1002/jae.951

Pesaran MH, Shin Y, Smith RP (1999) Pooled mean group estimation of dynamic heterogeneous panels. J Am Stat Assoc 94(446):621–634

Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. J Appl Econom 16(3):289–326. https://doi.org/10.1002/jae.616

Ren S, Yuan B, Ma X, Chen X (2014) International trade, FDI (foreign direct investment) and embodied CO_2 emissions: a case study of Chinas industrial sectors. China Econ Rev 28:123–134. https://doi.org/10.1016/j.chieco.2014.01.003

Sadorsky P (2010) The impact of financial development on energy consumption in emerging economies. Energy Policy 38:2528–2535

Saidi K, Mbarek MB (2017) The impact of income, trade, urbanization, and financial development on CO_2 emissions in 19 emerging economies. Environ Sci Pollut Res 24:12748–12757. https://doi.org/10.1007/s11356-016-6303-3

Salahuddin M, Gow J, Ozturk I (2015) Is the long-run relationship between economic growth, electricity consumption, carbon dioxide emissions and financial development in Gulf Cooperation Council Countries robust? Renew Sustain Energy Rev 51:317–326. https://doi.org/10.1016/j.rser.2015.06.005

Santiago R, Fuinhas JA, Marques AC (2018) The impact of globalization and economic freedom on economic growth: the case of Latin America and Caribbean countries. Econ Change Restruct. https://doi.org/10.1007/s10644-018-9239-4

Shahbaz M, Hye QMA, Tiwari AK, Leitão NC (2013a) Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. Renew Sustain Energy Rev 25:109–121. https://doi.org/10.1016/j.rser.2013.04.009

Shahbaz M, Khan S, Tahir MI (2013b) The dynamic links between energy consumption, economic growth, financial development and trade in China: fresh evidence from multivariate framework analysis. Energy Econ 40:8–21. https://doi.org/10.1016/j.eneco.2013.06.006

Shahbaz M, Solarin SA, Mahmood H, Arouri M (2013c) Does financial development reduce CO_2 emissions in the Malaysian economy? A time series analysis. Econ Model 35:145–152. https://doi.org/10.1016/j.econmod.2013.06.037

Shahbaz M, Tiwari AK, Nasir M (2013d) The effects of financial development, economic growth, coal consumption, and trade openness on CO_2 emissions in South Africa. Energy Policy 61:1452–1459. https://doi.org/10.1016/j.enpol.2013.07.006

Tamazian A, Rao BB (2010) Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. Energy Econ 32(1):137–145. https://doi.org/10.1016/j.eneco.2009.04.004

Tamazian A, Chousa JP, Vadlamannati KC (2009) Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries. Energy Policy 37(1):246–253. https://doi.org/10.1016/j.enpol.2008.08.025

Westerlund J (2007) Testing for error correction in panel data. Oxford Econ Stat 31(2):217–224

Wooldridge JM (2002) Econometric analysis of cross section and panel data. The MIT Press Cambridge, Massachusetts

World Bank Data (2018). http://databank.worldbank.org/data/home.aspx

You W-H, Zhu H-M, Yu K, Peng C (2015) Democracy, financial openness, and global carbon dioxide emissions: heterogeneity across existing emission levels. World Dev 66:189–207. https://doi.org/10.1016/j.worlddev.2014.08.013

Zilio M, Recalde M (2011) GDP and environment pressure: the role of energy in Latin America and the Caribbean. Energy Policy 39(12):7941–7949. https://doi.org/10.1016/j.enpol.2011.09.049

Zoundi Z (2017) CO_2 emissions, renewable energy, and the environmental Kuznets curve, a panel cointegration approach. Renew Sustain Energy Rev 72:1067–1075. https://doi.org/10.1016/j.rser.2016.10.018