

# Do fiscal incentive policies impact the installed capacity of renewable energy? An empirical evidence from Latin American countries

## Abstract

Matheus Koengkan<sup>1</sup>

The impact of fiscal incentive policies on the installed capacity of renewable energy was examined in thirteen Latin American countries, over the period of 1980 to 2014. The Autoregressive Distributed Lag (ARDL) methodology was used to decompose the total effect of fiscal incentive policies on installed capacity in its short- and long-run components. The results showed that the fiscal incentive policies in short-run do not cause any impact on the installed capacity of renewable energy, due to the possible inefficiency of these policies, while in long-run, the fiscal incentives stimulate the investments in renewable energy in 0.8977 %. The economic growth of Latin American countries and economic growth of China in the short-run have a positive impact of 3.1564 %, and 5.2724 % respectively, while in long-run exerts a positive influence of 2.4934 % and 1.0498 %. The results of this article point to the necessity to create more fiscal incentive policies in order to promote the investments in renewable energy sources, to foster the economy of countries or specific regions, as well as generate income, and also increases the consumption of alternative sources.

**Keywords:** Fiscal incentive policies, renewable energy, energy policies, energy economics.

## As políticas de incentivos fiscais afetam a capacidade instalada de energia renovável? Uma evidência empírica de países da América Latina

### Resumo

O impacto das políticas de incentivo fiscal sobre a capacidade instalada de energia renovável foi examinado em treze países latino-americanos, durante o período de 1980 a 2014. A metodologia *Autoregressive Distributed Lag* (ARDL) foi utilizada para decompor o efeito total das políticas de incentivo fiscal na

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<sup>1</sup> Mestrando em Ciências Econômicas pela Universidade da Beira Interior (Portugal), Pós-graduado em Controladoria e Finanças pela Universidade Federal Fluminense-UFF (2015), Bacharel em Ciências Contábeis pelo Centro Universitário de Volta Redonda UniFOA (2013). Atualmente pesquisador nas áreas da Economia da Energia e Finanças.

capacidade instalada em seus componentes de curto e longo prazo. Os resultados mostraram que as políticas de incentivo fiscal em curto-prazo não causam impacto na capacidade instalada de energia renovável, devido à possível ineficiência dessas políticas, enquanto que a longo-prazo, os incentivos fiscais estimulam os investimentos em energia renovável em 0.8977%. O crescimento econômico dos países latino-americanos e o crescimento econômico da China no curto prazo têm um impacto positivo de 3.1564% e 5.2724%, respectivamente, enquanto no longo prazo exerce uma influência positiva de 2.4934% e 1.0498%. Os resultados deste artigo apontam para a necessidade de criar mais políticas de incentivo fiscal para promover os investimentos em fontes de energia renováveis, promover a economia de países ou regiões específicas, bem como gerar renda e também aumentar o consumo de fontes alternativas .

**Palavras-chave:** Políticas de incentivo fiscal, energias renováveis, políticas energéticas, economia da energia.

**JEL Classification:** C33, Q01, Q20, Q28, Q43

## **1. Introduction**

The renewable energy becoming a priority for Latin American countries in the last three decades. This priority is due to the increases in environmental degradation, the rapid energy demand, the high-energy prices in most of the countries in the Latin American region, and the abundance of renewable energy sources like hydropower, geothermal, solar, wind (Fuinhas et al.2017). These factors influence the deployment of several policies, such as the fiscal incentives to support the renewable energy sources.

The fiscal incentive policies most common in the Latin American countries are the feed-in tariffs that are mechanisms that accelerate the investments in renewable energy technologies, and energy producers. These policies are typically based on the cost of generation of each technology; Tariffs/premiums are policies that the renewable energy producers receive a premium on top of the market price of their energy production. This kind of policies can be fixed or sliding; Grants/subsidies and loans are policies that give subsidies and loans with

low-interest rates for firms and households purchase renewable energy technologies.

The first country which adopted the fiscal incentive policies was Brazil in 1975 with the establishment of the *ProÁlcool* biofuels programme. Other countries adopted the same policies, such as Costa Rica in 1987 and Nicaragua in 1977 with geothermal laws (IRENA,2015; Fuinhas et al. 2017).

In the literature, several authors have investigated the impact of fiscal incentive policies on the installed capacity of renewable energy. One example is Curtin et al. (2017) that investigated the impact of feed-in tariffs, feed-in premium, quota schemes, tax incentives, grants, subsidies, and soft loans on developing of renewable energy. The authors found that the feed-in tariffs, grants, and tax incentives can be successful in mobilizing greater levels of investment in low carbon technologies except for the soft loans. Servet et al. (2014) studied the impact of financial, and fiscal Incentives for the development of utility-scale solar energy projects in the north of Chile. The results pointed that the solar energy projects become more competitive than fossil fuel projects due to financial, and fiscal incentives. Smith and Urpelainen (2014) investigated in 26 industrialized countries in a period from 1979–2005 the impact of feed-in tariffs on renewable electricity generation. The results showed that the feed-in tariffs increase the generation of renewable energy.

The aim of this study is to answer the following question: Are the fiscal incentive policies increasing the installed capacity of renewable energy? In order to answer this question, the impact of fiscal incentive policies on the installed capacity of renewable energy will be analyzed for thirteen Latin American countries in a period from 1980 to 2014, using Unrestricted Error Correction Model (UECM) form of the Auto-Regressive Distributive Lag (ARDL). The study of this theme is fundamental to be able to understand the real impact of fiscal incentive policies on the installed capacity of renewable energy in the Latin American countries. The choice of these countries is justified due to the rapid growth of installed capacity of renewable energy in the Latin America region.

This article is organized as follows: Section 2, will present a brief literature review. Section 3, the methodology, databases, and preliminary tests that were used. Section 4, the empirical results. Section 5, discussions. Finally, the conclusions and policy implications are shown in Section 6.

## 2. Literature Review

The impact of fiscal incentive policies on the installed capacity of renewable energy has been researched in the literature. The studies that approach the fiscal incentive policies have been centered on three policies, such as, feed-in tariffs (FITs), premium payments, and grant/subsidies. In fact, in the literature, there is evidence that these policies contribute to increase of installed capacity of renewable energy. Table 1 presents a summary of the literature review.

**Table 1.** Summary of literature review

Author(s)	Period	Country(ies)	Policy(ies)	Conclusion(s)
Curtin et al. (2017)	n.a	n.a	Feed-in tariffs, Feed-in Premium; Quota schemes; Tax incentives; Grants and subsidies; "Soft" loans.	The feed-in tariffs, grants, and tax incentives can be successful in mobilizing greater levels of investment in low carbon technologies, but the soft loans are less effective.
Crago and Chernyakhovskiy (2017)	2005-2012	United States	Income tax credit; Rebate; RPS; Sales tax exemption; Solar rights regulation; Third-party ownership.	The financial incentives increase the annual photovoltaic capacity additions by close to 50%.
Aquila et al. (2017)	1990-2012	Brazil	Feed-in tariffs.	The Feed-in tariffs promote the use of renewable energy sources.
Sarzynski et al. (2016)	1997-2009	United States	Income tax incentives; Cash incentives; Sales tax incentives and property tax incentives.	The photovoltaic capacity installed increased by approximately 2%.
Thapar et al. (2016)	n. a.	India	Grant/subsidies; Tax concessions/exemption and preferential tariffs.	The renewable energy policies instruments accelerating the installed capacity of renewable energy.
Fowler and Breen (2014)	1975-2005 2006-2007 1983-2007	United States	Tax incentives, grants and loan program.	The financial incentives have great promise of encouraging the penetration of renewable energy into the mark.
Simsek and Simsek (2013)	2000-2010	Turkey	Feed-in tariffs, Obligatory green Certificates, exemptions, deductions, incentives, Investment Incentive.	Incentives in Turkey have led to more investment in renewable energy generation.
Jacobs et al. (2013)	2010	Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Jamaica, Mexico, Peru, St. Lucia, St. Vincent and	Feed-in tariffs.	the feed-in tariffs policies in the Latin American countries have led to limited renewable energy development because the rates are based on avoided cost (and therefore are too low). Setting low rates based

		Grenadines and Uruguay		on avoided cost is consistent with the goal of limiting ratepayer exposure to renewable energy policy costs, but it also restricts investment in the new capacity of renewable energy sources.
Ortega et al. (2013)	2002-2011	Spain	Feed-in tariffs.	The feed-in tariffs promote to increase of installed capacity of renewable energy.
Stokes (2013)	1997-2012	Canada	Feed-in tariffs.	The feed-in tariffs have the capacity to develop the renewable energy sources.

**Notes:** n. a. denotes 'not available'. The table was created by the author.

The literature provides that the fiscal incentive policies have contributed to increase of installed capacity of renewable energy.

### 3. Data and Methodology

This section is divided into three parts. In the first one, it will be presented the data used in this research. The second section contains the methodology used. The third approaches preliminary tests.

#### 3.1 Data

To analyze the impact of fiscal incentives policies on the installed capacity of renewable energy, it was utilized the data from 1980 to 2014 of thirteen Latin American countries, such as Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela. The variables used in our analysis were:

**Table 2.** Variables used

Variables	Description	Source
Installed capacity of renewable energy	Install capacity of renewable energy sources in Million kWn include, hydropower, solar, photovoltaic, waste, biomass, geothermal, and wave.	Energy Information Administration (EIA).
Gross domestic product (GDP) <i>per capita</i>	GDP in constant local currency unity (LCU) and transformed in <i>per capita</i> values.	World Bank Data (WBD).
Gross domestic product (GDP) from China <i>per capita</i>	GDP of China in constant local currency unity (LCU) and transformed in <i>per capita</i> values.	World Bank Data (WBD).
Fiscal incentive policies	A cumulative number of Fiscal/financial incentive policies include (feed-in tariffs/premiums, grants and subsidies loans, tax relief, taxes, and user charges).	International Energy Administration (IEA/IRENA).

**Notes:** The table was created by the author.

The uses of *per capita* values let us control for disparities in population growth among the Latin American countries (Fuinhas et al. 2017;

Koengkan,2017), and thus the uses of local currency unit (LCU) reduces the influence of exchange rates. The uses of variable “GDP of China” is due to the economic growth of China has a positive impact on economic growth of Latin American countries and consequently in investments of renewable energy, as well as the China is an important drive in investments of this kind of sources. Table 3 shows the summary statistics of variables. The panel descriptive statistics can see in (Table A1).

**Table 3.** Variables used and summary statistics

Variables	Acronym	Obs	Mean	Std Dev.	Min	Max
Installed capacity of renewable energy	LogRescap	455	2.4606	3.4832	-2.3026	11.5872
Gross domestic product (GDP) from Latin American countries <i>per capita</i>	LogGDP_LA	455	10.6403	2.8274	7.2290	16.1937
Gross domestic product (GDP) from China <i>per capita</i>	LogGDP_China	455	9.1761	0.8676	7.7644	10.6299
Fiscal incentives policies	LogPolicies	455	0.4675	0.6467	0.0000	2.1972

**Notes:** The Stata command *sum* was used to achieve the summary statistics. (Log) denotes variables in natural logarithms; The table was created by the author.

Thus, to the realization of this analysis were utilized following softwares: Stata 14.0, and EViews 9.5.

### 3.2 Methodology

To analyze the impact of fiscal incentive policies on the installed capacity of renewable energy in thirteen Latin American countries, the Autoregressive Distributed Lag (ARDL) in the form of Unrestricted Error Correction Model (UECM) was applied. According to Fuinhas et al. (2017) and Koengkan (2017a), the ARDL methodology has a capacity to decompose the total effect of variables into in the short-and long-run components. Moreover, the authors complement that this methodology is consistent with efficient estimations and parameter inferences based on the standard test.

Therefore, to able to analyze the impact of financial incentive policies, the following equation was used:

$$LogRescap_{it} = \alpha_{0it} + \sum_{i=0}^k \beta_{2it} LogGDP\_LA_{it} + \sum_{i=0}^k \beta_{3it} LogGDP\_China_{it} + \sum_{i=0}^k \beta_{4it} LogPolicies_{it} + \alpha_{1it} \quad (1)$$

The prefixes (Log) used in equation denote the natural logarithms of variables. Certainly, the (LogRescap) is the dependent variable, and

(LogGDP\_LA, LogGDP\_China, and LogPolicies) are the independent variables in the model. The  $\Delta_{0it}$  is the intercept,  $\beta_{2it} \dots \beta_{4it}$  are the parameters of variables and  $\alpha_{1it}$  is the error term of the model. To decompose the dynamic relationship of short-and long-run variables, the following equation was used:

$$\Delta \text{LogRescap}_{it} = \Delta_{0it} + \sum_{i=0}^k \beta_{2it} \Delta \text{LogGDP\_LA}_{it} + \sum_{i=0}^k \beta_{3it} \Delta \text{LogGDP\_China}_{it} + \sum_{i=0}^k \beta_{4it} \Delta \text{LogPolicies}_{it} + \gamma_{1it} \text{LogRescap}_{it} + \gamma_{2it} \text{LogGDP\_LA}_{it} + \gamma_{3it} \text{LogGDP\_China}_{it} + \gamma_{4it} \text{LogPolicies}_{it} + \alpha_{2it} \quad (2)$$

The prefixes (Log) and ( $\Delta$ ) used in equation denote the natural logarithms and the first-differences of variables. The ( $\Delta \text{LogRescap}$  and  $\text{LogRescap}$ ) are the dependent variables, and (LogGDP\_LA,  $\Delta \text{LogGDP\_LA}$ , LogGDP\_China,  $\Delta \text{LogGDP\_China}$ , and LogPolicies,  $\Delta \text{LogPolicies}$ ) are the independent variables in the model. The  $\Delta_{0it}$  is the intercept,  $\beta_{2it} \dots \beta_{4it} \dots \gamma_{1it} \dots \gamma_{4it}$  are the parameters of variables and  $\alpha_{1it}$  is the error term of the model. Before regression, it is necessary to apply some preliminary tests to verify the characteristic of variables and their composition. The preliminary tests include:

- (i) Variance Inflation Factor (VIF-test) to checks the existence of multicollinearity between variables. This test, demonstrate the impact of multicollinearity in the accuracy of estimation regression coefficients (O'Brien,2007);
- (ii) Cross-section dependence (CSD-test) to analyze the presence of cross-section dependence between the variables. The null hypothesis of this test is the existence of cross-section independence (Pesaran,2004);
- (iii) First-generation unit root test which includes the LL (Levin, Lin, and Chu,2002), the ADF-Fisher (Maddala and Wu, 1999) and the ADF-Choi (Choi,2001). The null hypothesis rejection of this test is the existence o unit root;
- (iv) Second-generation unit root test (CIPS-test) to identify the integration order of variables (Pesaran, et al.2013). The null hypothesis rejection of this test is that the variable has a unit root or I(1), this is, the variable is stationary;

- (v) Westerlund cointegration test to check the cointegration between the variables (Westerlund, 2007);
- (vi) Hausman test specification test which compares an estimator that is known to be consistent with an estimator that is efficient under the assumption being tested (Hausman, 1978). In this case, this test will compare the Random Effects (RE) with individual Dynamic Fixed Effects (DFE);
- (vii) Mean Group (MG) or Pooled Mean Group (PMG) estimators to check the heterogeneity of parameters in the short-run and long-run. The MG is a technique that creates regressions for each cross and computes to all individuals an average coefficient (Fuinhas, et al., 2017). This estimator is consistent with the long-run average. However, in the presence of slope homogeneity this estimator is not efficient (Pesaran et al., 1999). The PMG estimator makes restrictions among cross-sections and adjustment speed term. This estimator in the existence of homogeneity in long-run, this estimator is more efficient than MG estimator (Fuinhas, et al. 2017).

Moreover, after regression, it is necessary to apply some model specification tests to verify the characteristics of the model. The model specification tests include:

- (i) Pesaran test of cross-section independence to identify the existence of contemporaneous correlation among cross-sections (Pesaran, 2007). The null hypothesis of this test specifies that the residuals are not correlated, and it follows a normal distribution;
- (ii) Breusch and Pagan Lagrange Multiplier test of independence to measure whether the variances across individuals are correlated (Breusch and Pagan, 1980);
- (iii) Wooldridge test to identify the existence of serial correlation (Wooldridge, 2002);
- (iv) Modified Wald test to detect the existence of groupwise heteroscedasticity in the residual of a fixed effect regression model (Greene, 2000);



- (v) Durbin-Watson statistic test to checks the presence of the first-order autocorrelation in the disturbance when all the regressors are strictly exogenous. The null hypothesis of the test is that there is no first-order auto-correlation (Verbeek, 2008 p. 373);
- (vi) Baltagi-Wu LBI test to test serial correlation in the disturbance. The null hypothesis of the test is no existence of first-order serial correlation (Baltagi, 2008, pp. 97-98);
- (vii) Pairwise Granger Causality test to certify the existence of causality between variables (Granger,1969).

### 3.3. Preliminary tests results

This section shows the preliminary tests in order to check the proprieties of the variables. To verify the presence of multicollinearity, and the presence of cross-section dependence between the variables, the VIF-test and CSD-test were applied. The results of both tests can be seen in Table 4.

**Table 4.** VIF test and Pesaran CSD-test

Variables	VIF	1/VIF	CD-test	Corr.	Abs (corr)
LogRescap	n. a.	n. a.	35.18 ***	0.673	0.673
LogGDP_LA	1.02	0.9831	38.89 ***	0.744	0.744
LogGDP_China	2.27	0.4407	52.25 ***	1.000	1.000
LogPolicies	2.27	0.4412	36.91 ***	0.706	0.706
Mean VIF	1.85				
ΔLogRescap	n. a.	n. a.	12.18 ***	0.237	0.314
ΔLogGDP_LA	1.04	0.9657	17.78 ***	0.345	0.347
ΔLogGDP_China	1.04	0.9652	51.50 ***	1.000	1.000
ΔLogPolicies	1.00	0.9988	3.12 ***	0.061	0.151
Mean VIF	1.02				

**Notes:** n. a. denotes 'not available'. \*\*\* denotes statistically significant at 1% level, respectively; (Log, and Δ) denotes variables in natural logarithms and the first-differences; The Stata command *xtcd* was used to achieve the results for CSD. The table was created by the author.

The results of VIF-test indicated that at the logarithms, the value of the mean of VIF was 1.85, and at the first-differences was 1.02. In both results, all individual VIFs are lower than the benchmark of 10%. These results, meaning that the multicollinearity between variables does not a problem in the model. The CSD-test indicate the existence of cross-section dependence in all variables in levels, and the first-differences. In the existence of cross-section dependence between variables, it is necessary to examine the stationarity proprieties of the variables included in the analysis.

The 1<sup>st</sup> generation unit root test and 2<sup>nd</sup> generation of unit root test (CIPS-test) were executed. The results of both tests can be seen in Table 5.

**Table 5.** Unit roots tests

Variables	1 <sup>st</sup> Generation test			2 <sup>nd</sup> Generation unit root test CIPS (Zt-bar)			
	LLC	ADF-Fisher	ADF-Choi	Without trend		With trend	
	Individual intercept and trend						
LogRescap	-0.9600	28.8690	-0.6103	-4.632	***	-3.893	***
LogGDP_LA	-3.0188	*** 37.8927	** -0.8801	-1.304	*	-1.090	
LogGDP_China	-3.1747	*** 89.8318	*** -6.6990	16.800		16.553	
LogPolicies	-0.2204	13.4522	1.3233	1.727		1.732	
ΔLogRescap	-8.6159	*** 160.742	*** -9.5295	*** -11.782	***	*** -11.087	***
ΔLogGDP_LA	-6.8976	*** 110.103	*** -7.4065	*** -6.946	***	*** -6.509	***
ΔLogGDP_China	-8.9594	*** 116.840	*** -8.2361	*** 16.800	***	*** 16.553	***
ΔLogPolicies	-9.7688	*** 98.2245	*** -7.0857	*** -7.088	***	*** -5.207	***

**Notes:** \*\*\*, \*\*, \* denote statistically significant at 1%, 5%, and 10% levels; (Log, and Δ) denote variables in natural logarithms and the first-differences; The null hypotheses are as follow: LLC test the unit root (common unit root process), this unit root test controls for individuals effects, individual linear trends, has a lag length 1, and Newey-West automatic bandwidth selection and Bartlett kernel were used; ADF-FISHER and ADF-Choi test the unit root (individual unit root process), this unit root test controls for individual effects, individual linear trends, has a lag length 1, the first generation test follows the option “individual intercept and trend”, which was decided after a visual inspection of the series. The EViews 9.5 was used in the calculus of the first-generation tests. The CIPS test has  $H_0$ : series are I (1). The Stata command *multipurt* was used to compute CIPS test. The table was created by the author.

The results of 1<sup>st</sup> generation unit root test indicate that variables in levels (LogGDP\_LA, and LogGDP\_China) are stationary, that has a unit root. Thus, the variables (LogRescap and LogPolicies) are non-stationary. Moreover, all variables in first-differences are stationary. The 2<sup>nd</sup> generation unit root test point that the variables in levels (LogRescap), without trend and trend, and (LogGDP\_LA) without trend are stationary and all variables in the first-differences are I (1). Therefore, to double-check the cointegration between the variables, the Westerlund test was used. Table 6 evidence the results of this test.

**Table 6.** Westerlund cointegration tests

Statistics	Westerlund cointegration test		
	Constant & trend		
	Value	Z-value	P-value robust
Gt	-2.488	0.895	0.400
Ga	-6.239	4.167	0.980
Pt	-8.570	0.331	0.338
Pt	-7.264	2.321	0.781

**Notes:** Bootstrapping regression with 800 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. The Stata command *xtwest* was used. The table was created by the author.

The Westerlund cointegration tests reject the existence of cointegration between variables. The non-detection of cointegration points to use of econometric techniques that are less stringent, i.e. ARDL models (Fuinhas et al. 2017 and Koengkan, 2017a; Koengkan, 2017b). To determine whether the panel has random or fixed effects, the Hausman test was performed. The result of Hausman test is statistically significant at 1 %  $\chi^2(7) = 50.91^{***}$ . The result

indicated to select the Dynamic Fixed Effects (DFE), model. Nevertheless, after the choice of DFE model the equation (2) is converted in Equation (3) by changing  $\alpha_{3it}$  for  $\theta_i + \delta_{it}$ , representing DFE model:

$$\Delta \text{LogRescap}_{it} = A_{0it} + \sum_{i=0}^k \beta_{2it} \Delta \text{LogGDP\_LA}_{it} + \sum_{i=0}^k \beta_{3it} \Delta \text{LogGDP\_China}_{it} + \sum_{i=0}^k \beta_{4it} \Delta \text{LogPolicies}_{it} + \gamma_{1it} \text{LogRescap}_{it} + \gamma_{2it} \text{LogGDP\_LA}_{it} + \gamma_{3it} \text{LogGDP\_China}_{it} + \gamma_{4it} \text{LogPolicies}_{it} + \theta_i + \delta_{it} \quad (3)$$

Where the prefixes (Log) and ( $\Delta$ ) used in equation denotes the natural logarithms and the first-differences of variables. The ( $\Delta \text{LogRescap}$  and  $\text{LogRescap}$ ) are the dependent variables, and ( $\text{LogGDP\_LA}$ ,  $\Delta \text{LogGDP\_LA}$ ,  $\text{LogGDP\_China}$ ,  $\Delta \text{LogGDP\_China}$ , and  $\text{LogPolicies}$ ,  $\Delta \text{LogPolicies}$ ) are the independent variables in the model. The  $\Delta_{0it}$  is the intercept,  $\beta_{2it} \dots \beta_{4it} \dots \gamma_{1it} \dots \gamma_{4it}$  are the parameters of variables, and  $\theta_i + \delta_{it}$  is the error term of the model. To check the heterogeneity of parameters in the short-run and long-run in the DFE model, the Mean Group (MG), and Pooled Mean Group (PMG) were applied. Table 7 shows the results of the heterogeneous test.

**Table 7. Heterogeneous estimator results**

(Dependent Variable $\Delta \text{LogRescap}/\text{LogRescap}$ )					
	Heterogeneous estimator				
	MG (I)	PMG (II)		DFE (III)	
Constant	-16.5338	-10.8807	***	-17.8941	***
	Short-run (semi-elasticities)				
$\Delta \text{LogGDP\_LA}$	1.9269	2.8031	**	3.1564	*
$\Delta \text{LogGDP\_China}$	8.3510	6.9996	***	5.2724	*
$\Delta \text{LogPolicies}$	0.4267	0.4051		0.2808	
	Long-run (elasticities)				
$\text{LogGDP\_LA} (-1)$	2.4934	2.4501	**	4.5249	***
$\text{LogGDP\_China} (-1)$	1.0498	0.7591	*	0.8479	*
$\text{LogPolicies} (-1)$	0.8977	2.6946	***	1.1045	*
	Speed of adjustment				
ECM(-1)	-0.5427	-0.3266	***	-0.3255	***
	Hausman test				
	MG vs PMG	PMG vs DFE		MG vs DFE	
	$\chi^2_8 = -25.54$	$\chi^2_8 = -17.76$		$\chi^2_8 = 2.32$	

**Notes:** \*\*\*, \*\*, \* denote statistically significant at 1%, 5%, and 10% level, respectively; (Log, and  $\Delta$ ) denote variables in natural logarithms and the first-differences; Hausman results for  $H_0$ : Difference in coefficients not systematic; ECM denotes error correction mechanism; the long-run parameters are computed elasticities; the Stata commands *xtpmg*, and Hausman (with the sigmamore option) were used; The table was created by the author.

The semi-elasticities were calculated by adding the coefficients of variables in the first-differences. The elasticities are calculated by dividing the coefficient of a lagged independent variable by the coefficient of the lagged

independent variable, multiplied by (-1).

The results of MG and PMG estimations indicate that the DFE is an appropriate estimator confirming the result of Hausman test, and thus that there is evidence that the panel is 'homogeneous'. After this test, the regression using the ARDL model, and the model specification tests were done.

#### 4. Empirical results

In this section, it is present the results of DFE model and the model specification tests. Table 8, evidence the results of DFE estimator.

**Table 8.** Estimation results

(Dependent Variable $\Delta\text{LogRescap}/\text{LogRescap}$ )				
	Dynamic Fixed effects			
	Coefficients	DFE (I)	DFE Robust (II)	DFE D.-K. (III)
Constant	-17.8941	***	***	***
Short-run (semi-elasticities)				
$\Delta\text{LogGDP\_LA}$	3.1564	*	***	*
$\Delta\text{LogGDP\_China}$	5.2724	*	**	
$\Delta\text{LogPolicies}$	0.2808			
Long-run (elasticities)				
$\text{LogGDP\_LA} (-1)$	2.4934	***	***	***
$\text{LogGDP\_China} (-1)$	1.0498	*		
$\text{LogPolicies} (-1)$	0.8977	*		*
Speed of adjustment				
ECM(-1)	-0.3255	***	***	***

**Notes:** \*\*\*, \*\*, \* denote statistically significant at 1%, 5%, and 10% level, respectively; (Log, and  $\Delta$ ) denote variables in natural logarithms and the first-differences; Hausman results for  $H_0$ : Difference in coefficients not systematic; ECM denotes error correction mechanism; the long-run parameters are computed elasticities, in the fixed effects were used the *xtreg* and *xtscc*. The table was created by the author.

The estimation results indicate that the fiscal incentive policies in the short-run do not cause an impact on the installed capacity of renewable energy and as expected, the economic growth of Latin American countries and China have a positive impact of 3.1564 % and 5.2724 % respectively. Moreover, in the long-run, the fiscal incentive policies have a positive impact of 0.8977 %, and the economic growth of Latin American countries and China exerts a positive influence of 2.4934 %, and 1.0498 % respectively.

The estimation results from the DFE, DFE robust standard errors, and DFE Driscoll and Kraay (DFE D.-K) point to presence of long memory in the variables and the presence of Granger causality, due to the Error Correction Model (ECM) term is statistically significant at 1 % level, and has a negative sign (e.g. Fuinhas et al., 2017; Koengkan, 2017a; Koengkan, 2017b). Thus, the Granger causality is caused, due to the ARDL model when expressed as a UECM has the capacity to decompose the total causality in short and long-run of variables (e.g. Fuinhas, et

al. 2017; Koengkan,2017a; Koengkan, 2017b; Jouini, 2014).

The battery of model specification tests was applied. Table 9, below shows the results of specification tests.

**Table 9.** Specification tests

Wooldridge test	Breusch-Pagan LM test	Modified Wald test	Pesaran test	Durbin-Watson statistics test	Baltagi-Wu LBI test
F(1,12) = 29.145***	$\chi^2_{78} = 546.392***$	$\chi^2_{13} = 1774.79***$	11.269***	1.9643***	2.0861***

**Notes:** \*\*\*, denotes statistically significant at 1% level, respectively; Stata commands; for  $H_0$  of Modified Wald test:  $\sigma(i)^2 = \sigma^2$  for all  $i$ ; results for  $H_0$  of Pesaran test: residuals are not correlated; results for  $H_0$  of Wooldridge test: no first-order autocorrelation; The Stata command *xtregar* was used in the Durbin-Watson statistics test and Baltagi-Wu LBI test: The null hypothesis of the Durbin-Watson statistics test is that there is no first-order autocorrelation, and Baltagi-Wu LBI test the null hypothesis of no first-order serial correlation. The table was created by the author.

The Wooldridge test which checks the existence of serial correlation points to the existence of the first-order autocorrelation. The Breusch-Pagan LM test points to the presence of correlation between variables. The Modified Wald test evidences the existence of heteroscedasticity. The Pesaran test points to the presence of cross-section independence. Finally, the Durbin-Watson statistics test and Baltagi-Wu LBI test indicate the existence of the first-order autocorrelation in the serial disturbance. To check the existence of causality between variables, Pairwise Granger Causality test was used. Table 10 shows the results of Pairwise Granger Causality test.

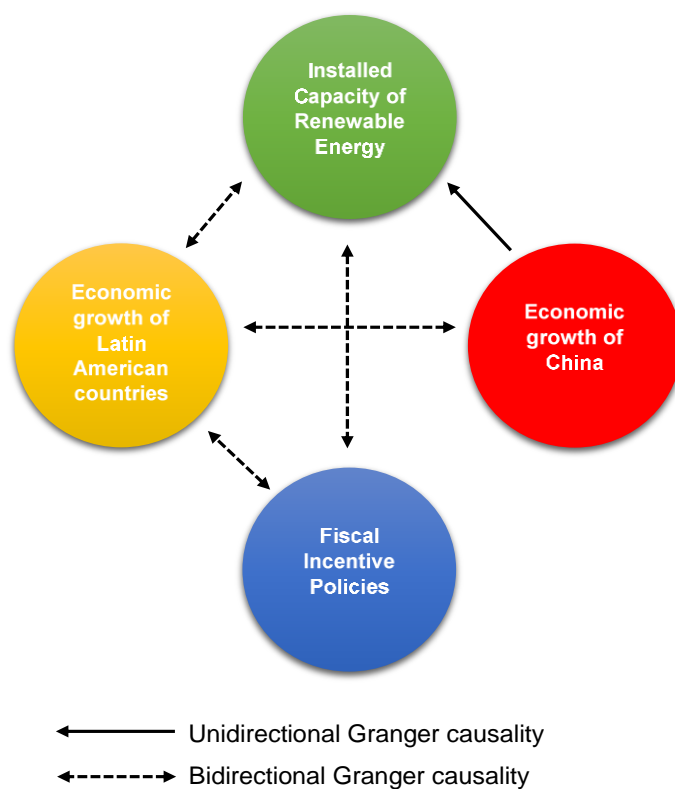
**Table 10.** Pairwise Granger Causality test

Null Hypothesis:	F-Statistic	Prob.
GDP_LA does not Granger Cause RESCAP	0.1185	0.8883
RESCAP does not Granger Cause GDP_LA	0.2974	0.7429
GDP_China does not Granger Cause RESCAP	0.2104	0.8103
RESCAP does not Granger Cause GDP_China	5.8928	0.0030 ***
POLICIES does not Granger Cause RESCAP	1.7171	0.1808
RESCAP does not Granger Cause POLICIES	0.6294	0.5334
GDP_China does not Granger Cause GDP_LA	1.0931	0.3361
GDP_LA does not Granger Cause GDP_China	1.5001	0.2243
POLICIES does not Granger Cause GDP_LA	1.8322	0.1613
GDP_LA does not Granger Cause POLICIES	0.0863	0.9173
POLICIES does not Granger Cause GDP_China	5.8175	0.0032 ***
GDP_China does not Granger Cause POLICIES	7.2272	0.0008 ***

**Notes:** The EViews 9.5 was used; \*\*\*, denotes statistically significant at 1 % level; This test was realization with lags (2). The table was created by the author.

The economic growth of Latin American countries causes an impact on the installed capacity of renewable energy, and the installed capacity of renewable

energy causes an impact on economic growth of Latin American countries. The economic growth of China causes an impact on installed capacity, and installed capacity does not cause an impact on economic growth of China. The fiscal incentive policies cause an impact on installed capacity, and the installed capacity causes an impact on fiscal incentive policies. The economic growth of China causes an impact on economic growth of Latin American countries, and the economic growth of Latin American countries causes an impact on economic growth of China. The fiscal incentive policies cause an impact on economic growth of Latin American countries, and the economic growth of Latin American countries (GDP) causes an impact on fiscal incentive policies. Finally, the fiscal incentive policies do not cause an impact on economic growth of China, and the economic growth of China does not cause an impact on fiscal incentive policies. Figure 1 summarizes the results of Pairwise Granger causalities test.



*Fig.1. Granger causality relationship flows*

Fig.1 shows that there is a bidirectional relationship between economic growth of Latin American countries, and installed capacity of renewable energy, and between installed capacity, and fiscal incentive policies, as well as, the economic growth of Latin American countries, and the fiscal incentive policies, and also the economic growth of Latin American countries, and the economic growth of China. Moreover, there is a unidirectional relationship between the economic growth of China and installed capacity of renewable energy.

## 5. Discussions

This study analyzes the impact of fiscal incentive policies on the installed capacity of renewable energy. The preliminary tests prove the existence of low multicollinearity, cross-section dependence, the presence of unit-root, non-cointegration of variables, and homogeneous panels. Moreover, the results of preliminary tests are in line with some investigates that approached the Latin America region (e.g. Koengkan, 2017a; Koengkan, 2017b; Fuinhas et al. 2017). The results in the short-run (semi-elasticities), and long-run (elasticities) of ARDL model indicate, that the incentive policies in the short-run do not cause any impact on installed capacity, while in the long-run the policies increase 0.8977 % the installed capacity. The economic growth of Latin American countries increases the installed capacity in 3.1564 % in short-run and in long-run 2.4934 %. Moreover, the economic growth of China increases the installed capacity of renewable energy in 5.2724 %, while in the long-run increases 1.0498 %. The ECM parameters of ARDL model is statistically significant at 1 % (-0.3255%\*\*\*). Indeed, the ECM is a version of Granger causality test and cointegration can ensure that both magnitudes of effects and causality are revealed by elasticities of themselves (see Table 8). Moreover, the results of specification test point to the presence of first-order autocorrelation, where the result of Wooldridge test was ( $F(1,12) = 29.145^{***}$ ), the presence of correlation between variables , where the result of Breusch-Pagan LM test was ( $\chi_{78}^2 = 546.392^{***}$ ), heteroscedasticity, where the result of Modified Wald test was ( $\chi_{13}^2 = 1774.79^{***}$ ), the presence of cross-section independence, where the results of Pesaran test was (11.269\*\*\*), and existence of the first-order autocorrelation in the serial disturbance, where the results of Durbin-Watson statistics test, and Baltagi-Wu LBI test were

(1.9643<sup>\*\*\*</sup>, and 2.0861<sup>\*\*\*</sup>) (see Table 9). The results of specification tests are statically significant at 1 %. The results of specification tests are in line with some investigates that approached the Latin America region (e.g. Koengkan, 2017a; Koengkan, 2017b; Fuinhas et al. 2017). The Pairwise Granger Causality test indicates the existence of a bidirectional relationship between economic growth of Latin American countries, and installed capacity of renewable energy, and between installed capacity, and fiscal incentive policies, as well as, the economic growth of Latin American countries, and the fiscal incentive policies, and also the economic growth of Latin American countries, and the economic growth of China. Moreover, there is a unidirectional relationship among the economic growth of China and installed capacity of renewable energy. Then, the incapacity of fiscal incentive policies in promote the installed capacity of renewable energy in short-run, is due to the inefficiency of renewable energy public policies in the Latin American countries, where the public policies are not able to promote the consumption, and investments in alternative energy sources in short-run, just in long-run (Fuinhas et al. 2017). Additionally, Jacobs et al. (2013), complements that the Feed-in tariffs policies in Latin American countries have a limited effect on renewable energy development because the policies are based on avoided cost, where it is too low. Indeed, the low rates limits the ratepayer exposure to renewable energy policy costs, and so it restricts the new investments in renewable energy sources in short-run. Moreover, the positive impact of fiscal incentive policies on installed capacity of renewable energy in long-run is confirmed by (e.g. Curtin et al. 2017; Crago and Chernyakhovskiy, 2017; Aquila et al. 2017; Sarzynski et al. 2016; Thapar et al. 2016; Fowler and Breen, 2014; Simsek and Simsek, 2013; Ortega et al. 2013; Ortega et al. 2013; Stokes, 2013). Indeed, the fiscal incentives policies encourage in the long-run the renewable energy development, due to the shifting the upfront cost from the private entities to investors willing to share the burden (Sarzynski et al. 2016). The FITs policies in long-run reduce the barriers and create opportunities for renewables to replace existing energy infrastructure and for the system to be decarbonized (Stokes, 2013).

The positive impact of the economic growth of Latin American countries on the installed capacity of renewable energy is due to increase of energy consumption, where the increase of 1 % of GDP, increases the consumption of



renewable energy in 3 % (Menegaki, 2011). The growing of energy consumption, increase the investments in installed capacity consequently. The influence of economic growth of China on the installed capacity of renewable energy in Latin American countries is due to the Chinese demand for primary commodities and direct investments flow that started in the 1990s, and that exerts a positive impact on economic growth of region (Jenkins et al., 2008). Then, the economic growth of China increases the GDP of Latin America region by nearly 0.02 % (Vianna, 2016). That is, the economic growth of China exerts an indirect impact on the installed capacity of renewable energy, where the increase of GDP of Latin American countries by China, influence the growth in energy consumption, and consequently the installed capacity.

## **6. Conclusions and policy implications**

The impact of fiscal incentive policies on the installed capacity of renewable energy was analyzed in this article, over the period of 1980 to 2014, in thirteen Latin American countries. The pre-testing proved the existence of low multicollinearity, cross-section dependence, the presence of unit-root, non-cointegration of variables and homogeneous panels. The results showed that the fiscal incentive policies in short-run do not cause any impact on the installed capacity of renewable energy, due to the possible inefficiency of these policies, while in long-run, the fiscal incentives stimulate the investments in renewable energy in 0.8977 %. The economic growth of Latin American countries and economic growth of China in the short-run have a positive impact of 3.1564 %, and 5.2724 % respectably, while in long-run exerts a positive influence of 2.4934 % and 1.0498 %. These positive effects are due to the economic growth of China which influences the economic development of Latin American countries by imports of commodities and services, and consequently, increase the energy consumption, and also subsequently encouragement the investments in installed capacity of renewable energy to supply the energy demand. The results of Granger Causality indicated that there is a bidirectional relationship between economic growth of Latin American countries, and installed capacity of renewable energy, and between installed capacity, and fiscal incentive policies, as well as, the economic growth of Latin American countries, and fiscal incentive policies, and also the economic growth of Latin American countries, and economic growth

in China. There is a unidirectional relationship between the economic growth of China and installed capacity of renewable energy. Based on these results: What it must be made to improve this current scenario in the Latin American countries? So the results of research points to the necessity to create more fiscal incentive policies in order to promote the investments in renewable energy sources, to foster the economy of countries or specific regions, as well as generate income and bring a better life quality also increase the consumption of alternative sources. Additionally, it is necessary to create policies more efficient to increase the economic competitiveness of Latin American countries and to create endogenous sources to create added value and generate jobs.

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## Appendix

**Table A1.** Panel descriptive statistics

Variables		Mean	Std.Dev	Min.	Max.	Observations
$\Delta$ LogRescap	Overall	0.1708	1.5650	-6.9112	7.2714	N = 442
	Between		0.1034	0.0173	0.2765	n = 13
	Within		1.5619	-7.0168	7.1889	T = 34
$\Delta$ LogGDP_LA	Overall	0.0129	0.0441	-0.1651	0.1504	N = 442
	Between		0.0090	-0.0008	0.0316	n = 13
	Within		0.0432	-0.1773	0.1642	T = 34
$\Delta$ LogGDP_China	Overall	0.0842	0.0248	0.0236	0.1278	N = 442
	Between		1.44e-1	0.0842	0.0842	n = 13
	Within		0.0248	0.0236	0.1278	T = 34
$\Delta$ LogPolicies	Overall	0.0419	0.1713	-0.4700	1.3862	N = 442
	Between		0.0182	0.0203	0.0646	n = 13
	Within		0.1704	-0.4754	1.3808	T = 34
LogRescap	Overall	2.4606	3.4832	-2.3025	11.5872	N = 455
	Between		2.1512	-1.2714	6.0397	n = 13
	Within		2.8020	-0.9821	9.3144	T = 35
LogGDP_LA	Overall	10.6403	2.8274	7.2289	16.1937	N = 455
	Between		2.9325	7.4928	15.7816	n = 13
	Within		0.1967	9.9749	11.2647	T = 35
LogGDP_China	Overall	9.1760	0.8676	7.7644	10.6299	N = 455
	Between		0.0000	9.1760	9.1760	n = 13
	Within		0.8676	7.7644	10.6299	T = 35
LogPolicies	Overall	0.4675	0.6467	0.0000	2.1972	N = 455
	Between		0.2011	0.1188	0.7384	n = 13
	Within		0.6171	-0.2709	2.3382	T = 35

**Notes:** The Stata command *xtsum* was used to achieve the results for panel between and within statistics; (Log, and  $\Delta$ ) denote variables in natural logarithms and the first-differences; The table was created by author.