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Economic Growth, Carbon Dioxide Emissions, Renewable Energy and Globalization

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ABSTRACT: This article investigates the correlation between economic growth, carbon dioxide emissions, renewable energy and globalization for the period 1970-2010, using time series (OLS, GMM, unit root test, VEC model, and Granger causality) to Portuguese economy. OLS estimator and GMM model demonstrate that carbon dioxide emissions and renewable energy are positively correlated with economic growth. The econometric models also show that the overall index of globalization has a positive effect on growth. The Granger causality reports a unidirectional causality between renewable energy and economic growth.

Keywords: Economic growth; renewable energy; globalization.
JEL Classifications: C13; F10; Q20

1. Introduction

This paper pretends to evaluate the linkages between economic growth, carbon dioxide emissions, energy efficient and globalization for Portuguese economy. The economic policy considers that globalization is a process that is correlated with international trade and foreign direct investment. In international agenda the role of IMF, WTO, and World Bank permit to explain that globalization is also correlated with poverty, crises, environmental rules, and climate changes. Indeed, the link between economic and globalization emerged in last years (Dreher, 2006; Gurgul and Lach, 2014). These studies show that globalization promotes the economic growth. The article of Dreher (2006) presents the arguments between globalization and economic growth. The author proposed a methodology to analyze the globalization, i.e., Dreher (2006) presents an indicator to evaluate the globalization. This index was knowledge as KOF index. This methodology involves three components: economic, social and political (Dreher, 2006; Dreher and Gaston, 2008). In 2006, Dreher uses a panel data (OLS estimator, and GMM-system estimator) to evaluate the relationship between globalization and growth. Gurgul and Lach (2014) consider the issue of globalization and economic growth for transition in ten CEE countries considering the period 1990- 2009. The authors use the globalization indexed suggest by Dreher (2006). As econometric strategy Gurgul and Lach (2014) apply OLS estimator, Fixed Effects and Random Effects. The authors show that social and economic globalization explains the economic growth. This study demonstrates that political globalization is not statistically significant. Recent empirical studies test the correlation between globalization and environmental change (Leitão and Shahbaz, 2013; Shahbaz et al. 2013). However, there are a vast of literature that to analyze the relationship between economic growth and the existence of environmental Kuznets curve (EKC).

Allen (2008:7-9) considers that human ecology economics involves four subjects: belief, social agreements, physical environments and resources, and human populations. Allen shows that the economic system is based on the beliefs, ideologies and mathematical models. The impact of renewable and non-renewable energy on economic growth is an issue of human ecology.

Shahbaz et al. (2013), Ozturk and Uddin (2012) are some examples. These studies consider as dependent variable carbon dioxide emissions to assess the environmental change. Usually the empirical studies use as explanatory variables GDP per, squared GDP per capita, energy consumption, openness trade, and foreign direct investment. Our study pretends to evaluate the new determinants of

economic growth. For that way, we assume that renewable energy, non- renewable energy and globalization explain the growth. In fact, energy efficient is crucial to explain the economic growth. Snyder (2008:73) explains that economic growth is complex, i.e., depends on what researchers want to explain and test. Thorpe and Leitão (2014:76-78) show that economic growth has been explained through foreign direct investment (FDI) and international trade. Some empirical studies also consider the fiscal and governmental policies. The explanatory variables as energy consumption, carbon dioxide emissions and the renewable energies have not been used very frequently to explain economic growth.

This research pretends to contribute to the existing empirical literature. At first we revisit the link between renewable and non-renewable energy and economic growth. The correlation between carbon dioxide emissions and growth, as well as, globalization and economic growth was analyzed. The econometric model is formulated based on the assumptions presented in the literature review. This study presents important findings for the Portuguese economy; these can be used by policy makers.

2. Literature Review and Empirical Studies

In this section, we revisit some empirical studies. Our main is to explain the new determinants of economic growth and their association with them. We decide to organize the literature review in four subjects: renewable energy and economic growth; energy consumption and economic growth; dioxide emission and economic growth, and globalization and economic growth.

2.1 Renewable Energy and Economic Growth

The empirical studies (Elliot 2007; Shahbaz et al. 2012; Sbia et al. 2014) demonstrate that the renewable energy promotes economic growth. These studies show that the renewable energy emits lower impact on environmental. Shahbaz et al. (2012) consider the correlation between renewable energy, nonrenewable energy, energy consumption, economic growth and endowment factors for Pakistan. The authors selected the period 1972-2011, using multivariate time series (unit root, ARDL for cointegration and VECM Granger causality). This study shows that the renewable energy promotes economic growth.

The linkage between foreign direct investment, renewable energy, openness trade and growth for the period 1975-2011 was analyzed by Sbia et al. (2014). The authors use as empirical strategy the unit roots, ARDL bounds and VECM Granger causality. Sbia et al. (2014) show that growth and renewable energy variables are positively correlated. However, the study of Vaona (2012) shows that the correlation between renewable energy and growth is not always positively. When the author applies the Granger causality and Toda and Yamamoto approach the renewable energy causes economic growth for the Italian case. Sadorsky (2009) considers a panel data from 18 emerging economies to explain the impact of renewable energy and growth. This empirical work shows that the renewable energy has a positive impact on economic growth. Apergis and Payne (2010) analyses the causality between renewable energy and economic growth utilizing panel data from OECD countries for the period 1985- 2005. The study shows that renewable energy, real gross fixed capital, labour force and real income per capita are correlated between them.

2.2 Energy Consumption and Economic Growth

This issue is explained by energy efficient versus energy inefficient. Emerging economies have high levels of energy dependence, when compared with developed countries. Most empirical models (Ozturk and Uddin, 2012; Dagher and Yacoubian 2012; Shahbaz et al. 2013) show a positive correlation between energy consumption and growth. The energy consumption and economic growth for OECD countries were analyzed by Bozoklu and Yilanci (2013). The authors found a permanent relation between the variables. Tang et al. (2013) investigate the energy consumption and growth for Portuguese economy. The authors apply a multivariate model (VECM, and Granger causality), and they found bidirectional causality between energy and economic growth. The correlation between economic growth, urbanization and energy consumption for Angola, was investigated by Solarin and Shahbaz (2013). The empirical results show that Angola is energy- depend country. A detailed literature survey on energy-growth nexus can be found in the study of Ozturk (2010).

2.3 Dioxide Carbon Emission and Economic Growth

Kim et al. (2010) consider the linkage between carbon dioxide emissions and economic growth for the case of Korea. Using Granger causality, the authors found causality between carbon

dioxide and growth. Economic growth and carbon dioxide emissions in Malaysia were analyzed by Saboori et al. (2012). This study considers the period 1980 to 2009. Using the theoretical hypothesis of Environmental Kuznets Curve and using ARDL approach and VECM, they found causality between dioxide carbon emissions and growth. However, Anderss-on and Karpestam (2013) demonstrate that the economic growth promotes a reduction of energy and dioxide emissions. This research considers the short and long-term determinants for developed and emerging economies for the period 1973-2007. The empirical work of Shahbaz and Leitão (2013) consider the relationship between economic growth and energy consumption for Portuguese case, applying the foundations of the existence of EKC. The authors utilize as econometric strategy the time series analysis (OLS estimator, and ARMA model). Shahbaz and Leitão (2013) found that the growth is positively correlated with energy consumption. Dagher and Yacoubian (2012) studied the causal relationship between energy consumption and growth in Lebanon for the period 1980-2009. The authors pretend to analyze the dynamic causal relationship between the variables. The results of Dagher and Yacoubian (2012) permit to conclude that energy consumption restring the economic growth in Lebanon.

2.4 Globalization and Economic Growth

The meta-analysis of this topic shows that there are two positions on the relationship between globalization and economic growth. The pessimistic position refers that globalization creates inequalities between countries. According to this point view, IMF, World Bank and World Trade Organization (WTO) have increased inequality between developed and emerging economies. The dominant paradigm shows that globalization encourages economic growth. Previous studies (Dreher, 2006; and Gurgul and Lach, 2014) show that there is a positive correlation between globalization and economic growth.

3. Data and Methods

Following the literature (Aperis and Payne, 2011; Shabaz et. al. 2012, Solarin and Shabaz 2013) we formulated the following equation:

$$Growth = \alpha_0 + \beta_1 \times RE + \beta_2 \times CO_2 + \beta_3 \times EC + \beta_4 \times GLOB + \varepsilon_{it} \qquad (1)$$

All variables are expressed in logarithm forms. The constant term is α_0. The coefficients for each variable take β_x. The error term is expressed by ε_{it}. The regression covers the period 1970-2010. The dependent variable is real GDP. The data was collected from World Bank, and Swiss Federal Institute of Technology Zurich. Table 1 presents the description of each variable. The econometric models were obtained with the Eviews software.

Table 1. Description of variables

Variables	Description of explanatory variables	Expected Signs
RE	Combustible renewable and waste (metric tons of oil equivalent)	+
CO_2	Carbon dioxide emissions (metric tons per capita)	+
EC	Energy use (Kg of oil equivalent per capita)	+; -
GLOB	Overall index of Globalization(see Dreher,2006)	+

In this research, we use a multivariate time series (OLS estimator, GMM, unit root test, and Granger causality). We apply Granger causality for VEC model to analyze the unidirectional or bi-directional causality between the variables.

4. Results and Discussion

Table 2 reports the determinants of economic growth using OLS estimator. We consider as explanatory variables renewable energy *(RE*), carbon dioxide emissions (CO_2), consumption of energy (*EC*), and globalization (*GLOB*). The coefficient of renewable energy (*RE*) is statistically significant at 5% level. According to previous studies (Elliot, 2007; Sadorsky, 2009; Shabaz et al. 2012; Sbia et al. 2014) the renewable energy is positively correlative with economic growth. The utilization of

renewable energy is essential for sustainable development. In fact, trade liberalization and international rules of environmental encourage the economies to use renewable energy, showing that these are an explanatory variable of growth. In a relationship the carbon dioxide emissions (CO_2) shows that the nonrenewable energy produces a positive impact on economic growth (Shabaz et al. 2012 and Sbia et al. 2014). The consumption of energy (*EC*) presents a negative sign, and the variable is statistically significant at 10%. This result is showing that Portugal is efficient of energy. In fact, Portugal in last years had decreased the dependent-energy level. The overall index of globalization (*GLOB*) presents a positive impact on economic growth. The empirical studies of Dreher (2006), and Gurgul and Lach (2014) also found a positive sign.

Table 2. OLS Estimator

Dependent Variable: *Growth*	
Independent Variables	OLS
RE	0.78 (2.16)**
CO_2	1.64 (5.27)***
EC	-0.26 (-1.79)*
GLOB	0.93 (1.71)*
Constant	-0.41 (0.50)
Adj. R^2	0.96
Observations	39

Note: ***, ** and * show significant at 1%,5%, 10% levels respectively.
OLS model (heteroskedasticity corrected) are in round brackets.

Table 3 presents the results with the Generalized Method of Moments (GMM) using time series. The results present some differences when we consider GMM estimator. The coefficients of renewable energy (*RE*), and carbon dioxide emissions (CO_2) have a positive impact on economic growth. The results also show that energy consumption (*EC*) is negatively correlated with growth. The coefficient of globalization (*GLOB*) presents a negative sign but without significance.

Table 3. GMM Estimator

Dependent Variable: *Growth*				
Method: Generalized Method of Moments				
Sample: 1970- 2010				
White Covariance				
Simultaneous weighting matrix & coefficient iteration				
Convergence achieved after: 17 weight matrices, 18 total coefficient iterations				
Instrument list: *Growth; RE;* CO_2 *EC; GLOB*				
Variables	Coefficient	Std. Error	t-Statistic	Prob.
RE	1.513383	0.238172	6.354158***	0.0000
CO_2	0.584331	0.204972	2.850787***	0.0071
EC	-0.260408	0.058699	-4.436357***	0.0001
GLOB	-0.207813	0.303810	-0.684023	0.4982
R-squared	0.905285	Mean dependent var		3.775610
Adjusted R-squared	0.897605	S.D. dependent var		0.412697
S.E. of regression	0.132060	Sum squared resid		0.645272
Durbin-Watson stat	0.185397	J-statistic		0.276336

Note: *** shows significant at 1% level.

Following the empirical literature (Tiwari, 2011; Ozturk and Uddin, 2012; Tiwari et al., 2013; Chang et al., 2013; Withey, 2014) we apply the unit root tests (the Augmented Dickey-Fuller [ADF], Phillips-Perron [PP] and Kwiatkowiski- Phillips- Schmidt.Shin [KPSS]). With the tests of ADF and PP, the variables are stationary (the first difference).

Table 4 . Unit root tests: ADF, PP and KPSS

Trend and intercept	Level			First difference		
Variables	ADF	PP	KPSS	ADF	PP	KPSS
Growth	-3.030*** (1)	-1.925* (1)	0.101** (4)	-4.004*** (0)	-3.584** (10)	0.050 (2)
RE	-2.366**(1)	-2.008* (2)	0.099 (5)	- 4.289*** (0)	-4.216*** (4)	0.1427*** (1)
CO_2	-0.7234 (0)	-0.960 (4)	0.148*** (4)	-2.466** (2)	-6.238*** (4)	0.096 (4)
EC	-1.633(0)	-1.729 (1)	0.108* (4)	-5.796*** (0)	-5.796*** (1)	0.104** (1)
GLOB	-2.413**(1)	-1.972 (2)	0.119*** (5)	-3.876*** (0)	-3.818*** (3)	0.093(2)
*** ** *, indicate significant at 1%, 5%, and 10% level. The parentheses represent the lag order.						

In table 5 and table 6 we can observe the test of cointegration proposed by Johansen (1995). The results suggest a cointegration between variables at 5% level of significance. Table 7 reports the results for Vector error correction model (VECM).

Table 5. Cointegration test: Unrestricted Cointegration Rank Test (Trace)

Hypothesized		Trace	0.05
No. of CE(s)	Eigenvalue	Statistic	Critical Value
None *	0.725821	95.59389	69.81889
At most 1	0.470329	45.12894	47.85613
At most 2	0.334121	20.34447	29.79707
At most 3	0.099187	4.485241	15.49471
At most 4	0.010493	0.411390	3.841466
Trace test indicates 1 cointegrating equations at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values			

Table 6. Cointegration test Rank Test (Maximum Eigenvalue)

Hypothesized		Max-Eigen	0.05
No. of CE(s)	Eigenvalue	Statistic	Critical Value
None *	0.725821	50.46495	33.87687
At most 1	0.470329	24.78447	27.58434
At most 2	0.334121	15.85923	21.13162
At most 3	0.099187	4.073850	14.26460
At most 4	0.010493	0.411390	3.841466
Max-eigenvalue test indicates 1 cointegrating equations at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values			

The economic growth (*Growth*) presents a positive impact in the long run. This result is according to previous studies (Gurgul and Lach, 2014). For the vector of economic growth, the energy consumption (*EC*) presents a negative impact on economic growth in the long run. The coefficient of globalization (*GLOB*) is negatively correlated with growth (Snyder 2008: 71-78). This result is in line with the anti-globalization philosophy. In the book edited by Allen (2008), Snyder explained why globalization can assume different perspectives.

Table 7. VEC model

Vector Error Correction Estimates					
Included Observations : 39 after adjustment					
Standard errors in ( ) & t- statistics []					
	DGrowth	*DRE*	DCO_2	*DEC*	*DGLOB*
DGrowth(-1)	0.339676***	-0.243651*	0.091941	-0.687372	0.006303
	(0.16335)	(0.12657)	(0.10781)	(0.52787)	(0.02761)
	[2.07949]	[-1.92503]	[0.85279]	[-1.30216]	[0.22832]
DRE (-1)	0.420598	0.108459	0.104356	-0.102434	0.064069
	(0.30015)	(0.23257)	(0.19811)	(0.96997)	(0.05073)
	[1.40129]	[0.46634]	[0.52677]	[-0.10560]	[1.26296]
DCO_2(-1)	0.041902	0.711472***	-0.002409	3.485239***	-0.015036
	(0.28089)	(0.21765)	(0.18539)	(0.90774)	(0.04747)
	[0.14917]	[3.26885]	[-0.01299]	[3.83948]	[-0.31672]
DEC(-1)	-0.149958*	0.142404**	-0.035221	0.158140	0.015922
	(0.08553)	(0.06628)	(0.05645)	(0.27641)	(0.01446)
	[-1.75323]	[2.14866]	[-0.62389]	[0.57212]	[1.10139]
DGLOB (-1)	-2.379650***	-0.237139	-0.251508	-0.217479	0.294716**
	(0.85399)	(0.66172)	(0.56365)	(2.75977)	(0.14433)
	[-2.78651]	[-0.35837]	[-0.44621]	[-0.07880]	[2.04189]
C	0.033981***	0.010337	0.009597	0.016070	0.002375
	(0.01032)	(0.00800)	(0.00681)	(0.03335)	(0.00174)
	[3.29256]	[1.29255]	[1.40888]	[0.48182]	[1.36168]
Adj. R-squared	0.238441	0.460560	-0.100912	0.276401	0.475644
Sum sq. Resids	0.059421	0.035677	0.025885	0.620555	0.001697
S.E. equation	0.043092	0.033390	0.028441	0.139256	0.007283
F-statistic	2.982938	6.407243	0.419475	3.419214	6.744975
Log likelihood	71.15148	81.09937	87.35544	25.40511	140.4850
Akaike AIC	-3.289820	-3.799968	-4.120792	-0.943852	-6.845385
Schwarz SC	-2.991232	-3.501380	-3.822204	-0.645264	-6.546797
Mean dependent	0.033545	0.016699	0.011640	0.038740	0.005790
S.D. dependent	0.049379	0.045462	0.027107	0.163707	0.010058
Determinant resid covariance (of adj.)		1.34E-16			
Dterminant residual covariance		4.97E-17			
Log likelihood		455.3486			
Akaike information criterion		-21.29993			
Schwarz criterion		-19.59371			

Note: ***, ** and * show significant at 1%, 5%, 10% levels respectively.

When we apply VECM we conclude that globalization promotes the poverty and inequality (Snyder 2008: 75). However, this result is contradictory that we obtained with the OLS estimator. The equation of renewable energy (*RE)* presents three statistically significant variables (economic growth, carbon dioxide emissions, and energy consumption). These results are according to the ideas defended by Moseidjord (2008), and Allen (2008). The climate change involves the study of social sciences, and other sciences (Moseidjord 2008: 189-190).

Table 8 presents the results of the causal relationship among economic growth (*Growth*), renewable energy (*RE*), carbon dioxide emissions (CO_2), energy consumption (*EC*), and the index of overall globalization (*GLOB*) for each equation used in the VEC model. According to table 7, we can observe that renewable energy consumption and energy consumption present bidirectional causality. The same is valid for renewable energy and globalization. The economic growth presents a unidirectional causality with the following variables: renewable energy, and globalization. However, the carbon dioxide emissions present causality with energy consumption, renewable energy and globalization.

Table 8. Granger causality tests

Null Hypothesis:	Obs	F-Statistic	Probability
CO_2 does not Granger Cause *Growth*	39	0.85571	0.43393
Growth does not Granger Cause CO_2		0.55092	0.58148
EC does not Granger Cause *Growth*	39	0.22355	0.80084
Growth does not Granger Cause *EC*		2.45659	0.10081
RE does not Granger Cause *Growth*	39	1.18337	0.31854
Growth does not Granger Cause *RE*		3.44813	0.04330
GLOB does not Granger Cause *Growth*	39	0.95801	0.39377
Growth does not Granger Cause *GLOB*		5.51359	0.00843
EC does not Granger Cause CO_2	39	0.27895	0.75830
CO_2 does not Granger Cause *EC*		11.5261	0.00015
RE does not Granger Cause CO_2	39	1.52304	0.23255
CO_2 does not Granger Cause *RE*		8.77862	0.00084
GLOB does not Granger Cause CO_2	39	0.41953	0.66071
CO_2 does not Granger Cause *GLOB*		9.33470	0.00059
RE does not Granger Cause *EC*	39	3.11405	0.05730
EC does not Granger Cause *RE*		3.46392	0.04274
GLOB does not Granger Cause *EC*	39	0.95323	0.39556
EC does not Granger Cause *GLOB*		25.7239	1.6E-07
GLOB does not Granger Cause *RE*	39	2.49750	0.09727
RE does not Granger Cause *GLOB*		16.5890	9.4E-06

5. Conclusions and Recommendations

This research evaluates the linkage between economic growth, carbon dioxide emissions, renewable energy and globalization. In this study, we apply a time series analysis (OLS, GMM, VEC model and Granger causality) for the period 1970-2010. The results show that globalization and renewable energy are positively correlated with the economic growth. We can conclude that globalization and renewable energy is a vehicle that encourages the environmental rules. With VECM, the coefficient of globalization presents a negative impact on economic growth. The result obtained to globalization is inconclusive. However, the energy consumption presents a positive effect

on economic growth with OLS. This result is in line of studies of Shabaz et al. (2012) and Sbia et al. (2014). The econometric results with Generalized Method of Moments (GMM) using time series are similar. Considering the VEC model, lagged energy consumption variable is negatively correlated with growth, reinforcing the use of renewable energy.

In terms of policy recommendations, this study demonstrates that the use of renewable energy is essential to obtain sustainable development. Granger causality demonstrates that the carbon dioxide emissions present causality with energy consumption, renewable energy and globalization. In further works, it will be necessary consider other variables in the regressions as the urban population, corruption, and democracy. According to the literature, these variables are also important determinants of economic growth. In our point view could be interesting to test the correlation with these variables and the climate changes and the economic growth.

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