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Cross Country Evidence on the Cointegration and Causality Relationships Between Economic Growth and CO2 Emissions in OECD Countries

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Abstract

This article aims to verify the existence of a relationship of cointegration and causality between economic growth and CO_2 emissions in 22 member countries of the OECD, in a time series from 1961 to 2011. The results indicate that economic growth and CO_2 are in balance in the long run for ten countries. The causality test showed a bilateral relationship, suggesting that variations in economic growth cause CO_2 emissions and CO_2 emissions cause economic growth. Long and short-term alternative measure, such as reforestation, the fight against deforestation, the use of wind, nuclear, and solar power, electric vehicles, incentives for the use of public transport, capture and storage of CO_2 are recommended for countries that CO_2 caused economic growth. Thus, it is concluded that there is evidence of long-term and causal relationships between economic growth and CO_2 emissions.

Key words: *Econometrics. OECD Countries. Sustainability. Time Series.*

1. INTRODUCTION

While discussions about the effects of global warming in different countries have shown greater prominence from the signing of the Kyoto Protocol in 1997, this issue had been argued by [9] when they proposed the Environmental Kuznets Curve hypothesis (EKC). This hypothesis suggested that the increase in the per capita income of a population would lead, over time, to an increase in the degradation of the environment; however, in environments where economic growth was more advanced, this relationship would tend to lose strength [9].

Under the effect of the perspective of the variables over time, published studies have used different economic variables and econometric techniques to verify the balance between the time series as well as the mutual effect of the variables. Most of the studies analyzed the temporal effect of different economic variables, such as per capita production [3], economic volatility [17], intensity of energy emissions [11] and economic growth [5]. More recently, these investigations also began to incorporate variables related to the environment such as CO_2 emissions and rate of growth of the population income [6] [20], energy consumption and CO_2 emissions [17], CO_2 [1], foreign direct investment, economic growth and CO_2 emissions [14] and the per capita electricity consumption [12].

When econometric techniques are used to evaluate the effects of the variables in different countries, their results suggest specific features of each context, they explained taking into account specific internal variations. Some countries have more lenient environmental laws and different percentages of economic development. The use of econometric tests with a combination of different variables can contribute to the discovery of new results related to the behavior of the series over time.

This article aims to verify the existence of a relationship of cointegration and causality between economic growth, here represented by GDP and CO2 emission levels in 22 member countries of the OECD. This study proposes through econometric techniques of cointegration and causality verify if economic growth and CO2 emissions are balanced in the long run, as well as the variations in the economic growth of a country also cause variations in the CO2 emissions, and whether it can cause economic growth. Econometric techniques were used to verify the behavior of these variables for each individual country over 50 years (1961-2011). We used the statistical package STATA 13.0 (Data Analysis and Statistical Software). [19] argue that it is relevant to investigate the effects of different variables because of the growing academic and managerial interest to create sustainable solutions that will contribute to social and ecological crises.

This study offers three main contributions to the discussion of the relationship between economic growth and CO_2 emissions. The first is the set of variables, economic growth represented by the Gross Domestic Product (GDP) and CO_2 emissions. Most studies investigate the economic growth using variables such as productivity or population income [6] [7] and other studies investigate economic growth combining variables such as energy consumption [11]. The second contribution is the behavior analysis of the variables from a 50-year time series, longer than 15-year time series [11], 30-year time series [12] [16] and longer than the 35-year series [7].

The third contribution is to verify how these relationships occur in the OECD member countries, as a support organization to sustainability practices with regard to the reduction of greenhouse gas emissions. Considering the argument of [20] that emissions of greenhouse gases and energy consumption have increased in OECD member countries, the econometric analysis might be able to point the existence of cointegration and causality between short-term or long-term public policies. These cointegrated series of information and causality relationships become important to indicate the more effective public policies. Considering the relations of cointegration and causality, this article indicates the adoption of public policies intended for an economy focused on sustainability, as pointed out by [19].

The article begins with the discussion of the economic growth and CO_2 emissions; next, the methodology is presented, detailing the construction process of this study. The next step is the description of the results and final considerations.

2. LITERATURE REVIEW

2.1 Economic Growth and CO_2 Emissions

One of the first studies on economic growth using the econometric method of time series was the study of [17]. The authors found that the higher the volatility between countries, the lower their economic growth. Other discussions have arisen relating different variables with economic growth. The time series of studies analyzed the economic growth of OECD countries with per capita output variables [3], energy [11] and economic growth [5]. More recently, these investigations also began to incorporate sustainability variables, such as CO_2 emissions and growth rate of the population income [6] [20], energy consumption and CO_2 emissions [7], CO_2 [1], foreign direct investment, economic growth and CO_2 emissions [14], and per capita electricity consumption [12].

Studies on economic growth and sustainability were widespread, particularly from discussions about global warming, as a result of emissions of greenhouse gases, mainly carbon dioxide (CO_2) [20]. Such discussions were also encouraged, both in the academic community and in political management, the hypothesis proposed by [9] and the Environmental Kuznets Curve (EKC). It was proposed that the increase in per capita income leads to further degradation of the environment; however, at the higher levels of economic growth this relationship tends to weaken and reduce the negative impact on the environment [20].

Although the arguments of the EKC hypothesis assert that economic growth in more advanced levels would bring the solution to environmental problems, [20] found that in the United States causality has not been confirmed between CO_2 emissions and income growth, thus reductions in income would not explain the reductions in emissions. The United States could not interfere in its economic growth in order to reduce CO_2 emissions, but they were able to take additional actions that did not interfere in this regard. [12] identified degree of dependence between economic growth and electricity consumption of 160 countries, sensitive to differences over a period of 30 years (1980 to 2010). [7] identified the existence of unidirectional causality between CO_2 emissions and economic growth, suggesting that the increase in energy consumption leads to an increase in income and volume of CO_2 emissions. The authors found no evidence that economic growth causes CO_2 emissions. [1] point out that the CO_2 emissions can be eliminated through technical energy conservation alternatives.

In the OECD country members, [11] found that the volume of greenhouse gas emissions was caused by the growth of GDP, population and energy consumption. Reductions in emissions of greenhouse gases would be linked to the economic climate of the country, the fall of the industrial sectors of the US and the EU services sector, reduced CO_2 emissions from 1992 to1997. Japan had a favorable economic climate and increased its energy intensity and emissions. New Zealand developed chemical and petrochemical industry, increasing the gas emission rates [11].

For a 30-year time series, [6] found evidence of cointegration and causality between CO_2 emissions and the growth of population income in 88 countries. A two-way causal relationship was identified for South Africa, North America, Central America, South America, Eastern Europe and Western Europe, indicating that changes in income also cause changes in CO_2 emissions, and suggesting that the opposite also may occur. The results of the study by [20] differ, the results of their research found a one-way relationship between income growth and CO_2 emissions.

Economic growth is also an important source in the attraction of foreign direct investment, especially if the economy is still in the development stage. [14] found that foreign direct investment contributes to economic growth, leading to higher energy consumption and increases CO_2 emissions.

This result is attributed to the developing economies with strong industrialization, which adds to the volume of CO_2 emissions [14].

2.2 **Conceptual development of hypotheses**

In recent years, cointegration and causality investigations have employed variables that represent economic growth and environmental indicators. Whereas unidirectional and bidirectional relationships between these variables were found in different studies [6] [20] [14]. Based on these findings, the assumptions that guide this study are:

H_0: Economic growth, represented by the total GDP, and the volume of CO_2 emissions are not cointegrated;

H_1: Economic growth, represented by the total GDP, and the volume of CO_2 emissions are cointegrated;

H_2: Economic growth, represented by the total GDP, and the volume of CO_2 emissions do not have causal relationships;

H_3: Economic growth, represented by the total GDP, and the volume of CO_2 emissions have causal relationships.

3. MATERIALS AND METHODS

This quantitative-descriptive study makes use of econometric methods of time series to check for relationships of cointegration and causality between economic growth, represented by the total GDP in millions of dollars, and CO_2 emission levels, presented in kilo measurement units. Time series are analyzed to observe the behavior of these variables over a period of 50 years (1961-2011) in 22 member countries of the OECD. The countries are: Australia, Belgium, Canada, Denmark, Spain, United States, Finland, France, Greece, Holland, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Norway, New Zealand, Portugal, United Kingdom, Sweden and Turkey.

We chose these countries because they present complete information of the variables analyzed in the period from 1961 to 2011. The importance of investigating the OEDC countries refers to the fact they adopt good governance practices for sustainability and display a tendency for public policies aimed at reducing the volume of CO_2 emissions.

The time series measured economic growth by total GDP estimated in millions of dollars and sustainability by total CO_2 emissions in kilo units (kg) of OECD countries. The variables were extracted from the World Bank database (World Bank). We performed the analysis making use of a balanced panel, containing full details of the variables and observations. Thus, from the 34 member countries of the OECD, countries that did not have the information of the variables in the analyzed period were excluded (Germany, Austria, Chile, Korea, Slovakia, Slovenia, Estonia, Hungary, Mexico, Poland, Czech Republic and Switzerland).

To analyze the relationship of cointegration and causality, it is necessary to perform additional tests prior to the econometric analysis. The presence of autocorrelation and the integration of the series was verified in the same order, through the tests "d" Durbin-Watson and Breusch- Godfrey. For countries in which autocorrelation tests were confirmed, we applied the corrective measure Cochrane-Orccut.

The stationarity of series and a presence of a unitary root were verified using the Amplified Dickey-Fuller (ADF) and Phillips-Perron tests. One of the premises, of the time series analysis is that the original data must be stationary in a level and must have a unitary root. For the econometric treatment of data the series should be transformed into non-stationary with no unitary root. To accomplish the conversion, the time series become differentiated by the application of one (1) difference. The stationarity and unitary root tests are performed because of economic variables are likely to suffer some tendency over time [10].

The test of Johansen for cointegration was conducted based on the Trace Statistic, Maximum Value Test, and the Granger causality test. The data were estimated individually for each country, with the aid of STATA 13. The driving stages of the study can be seen in Figure 1.

4. RESULTS

The autocorrelation of the series was confirmed for all countries. After applying the Cochrane-Orccut test, as a corrective measure, the absence of the autocorrelation was confirmed when the transformed values of "d", the d Durbin-Watson test of the autocorrelation of the regression residuals, are concentrated in the absence of the autocorrelation intervals ($d_U < d < 4\text{-}d_U$), comparing the measurements of dL and dU values [10]. The Durbin-Watson test, assumes that the regression variables and stochastic errors follow a normal distribution [10]. The tests with the identification of the smallest gap in the series by the Akaike Information Criterion (AIC) and Schwartz Information Criterion (SBIC) were carried out; these tests are necessary to carry out the Dickey-Fuller Augmented stationarity (ADF) test and Phillips-Perron unit root. Identifying the best gap in time series is essential because the response of the dependent variables in a time series occurs by lapses in time, and its identification is the number of gaps [10].

The assumptions for the econometric analysis were confirmed by ADF and Phillips-Perron tests, indicating the nonstationarity of the series and the presence of a unit root, because the values of the betas were greater than one (1). We carried out the conversion of the series of all countries in 1 (a difference), making stationary and absence of unit root variables. The series turned into stationary when |t| statistic values exceed the critical values (|t|) [10]. Table 1 shows the results for the Dickey-Fuller Augmented test (ADF).

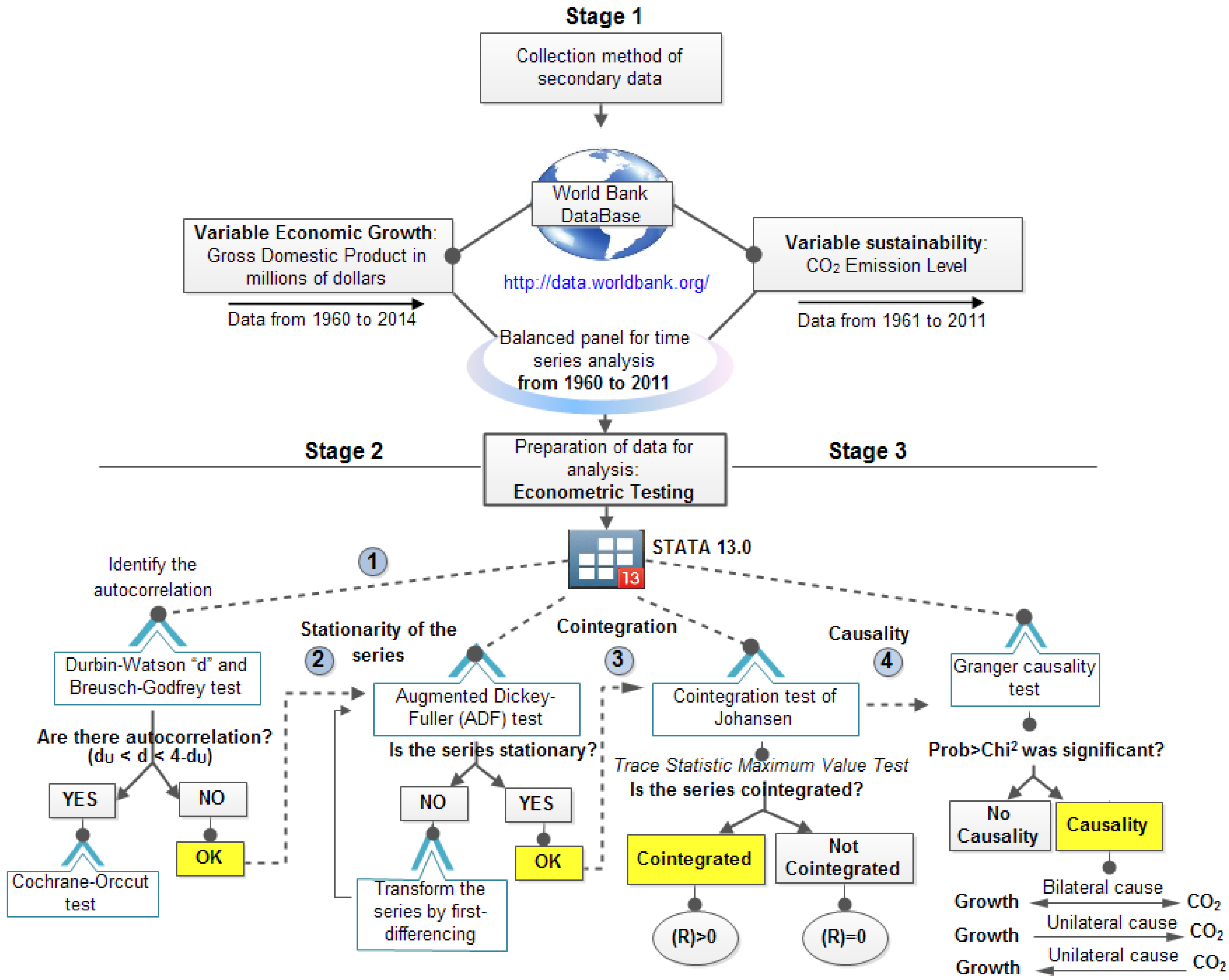

Figure 1. The conducting stages of this study
Source: Research data (2016).

Table 1. Unit root Dickey-Fuller test for variables economic growth and CO_2 emissions

Country	Statistical Test |t|		1% critical value	5% critical value	10% critical value	Result
	Growth	CO_2				
Australia	4,994	-8,213	-3,587	-2,933	-2,601	confirmed
Belgium	-4,310	-3,147	-3,587	-2,933	-2,601	confirmed
Canada	4,773	-2,693	-3,580	-2,930	-2,600	confirmed
Denmark	-5,785	-2,759	-3,587	-2,933	-2,601	confirmed
Spain	-4,393	-4,842	-3,587	-2,933	-2,601	confirmed
U.S	2,660	-2,613	-5,594	-2,936	-2,602	confirmed
Finland	-2,870	-2,790	-3,587	-2,933	-2,601	confirmed
France	-3,229	-6,894	-3,587	-2,933	-2,601	confirmed
Greece	-3,121	-2,796	-3,594	-2,936	-2,602	confirmed
Netherlands	-3,263	-2,870	-3,587	-2,933	-2,601	confirmed
Ireland	-2,992	-5,163	-3,607	-2,941	-2,605	confirmed
Iceland	2,664	-5,629	-3,600	-2,938	-2,604	confirmed
Israel	-4,780	-4,517	-3,594	-2,936	-2,602	confirmed
Italy	-5,543	-3,448	-3,587	-2,933	-2,601	confirmed
Japan	-7,194	-3,009	-3,587	-2,933	-2,601	confirmed
Luxembourg	4,060	-4,372	-3,607	-2,941	-2,605	confirmed
Norway	4,324	-4,053	-3,607	-2,941	-2,605	confirmed
New Zealand	-7,054	-6,831	-3,600	-2,938	-2,604	confirmed
Portugal	-6,538	-6,538	-3,614	-2,944	-2,606	confirmed
United Kingdom	2,691	-4,400	-3,594	-2,936	-2,602	confirmed
Sweden	3,401	-6,969	-3,587	-2,933	-2,601	confirmed
Turkey	2,781	-6,434	-3,594	-2,936	-2,602	confirmed

Source: Study Data (2016).

The data in Table 1 confirms the stationarity of the series when the value of |t| statistical test, verified in module is greater than the critical percentage. This test was confirmed for all countries and supports the carrying out of cointegration and causality tests. To verify the existence of a balance relationship in the long term between the variables economic growth and CO_2 emissions, we chose the cointegration Johansen test, based on the statistic trace test and Maximum Value Test. Table 2 shows the results.

Table 2. The Johansen cointegration test for the variables economic growth and CO_2 emissions

Countries	Rank (R)	Parms	LL	Eingen-value	Max. Statis.	5% critical Value	1% critical value	Result
Australia	1	9	-989,487	0,47	0,84^{*1*5}	3,76	6,65	cointegrated
Belgium	0	6	-953,252	-	14,83^{*1*5}	15,41	20,04	not cointegrated
Canada	1	9	-1098,96	0,40	0,0082^{*1*5}	3,76	6,65	cointegrated
Denmark	0	6	-1036,34	-	17,6542^{*1}	15,41	20,04	not cointegrated
Spain	1	9	-1000,20	0,630	3,9293^{*1}	3,76	6,65	cointegrated
U.S	0	6	-1293,65	-	13,052^{*1*5}	15,41	20,04	not cointegrated
Finland	0	6	-956,96	-	12,4012^{*5}	15,41	20,04	not cointegrated
France	0	6	-1116,89	-	11,9905^{*1*5}	15,41	20,04	not cointegrated
Greece	1	9	-907,08	0,35108	3,5227^{*1*5}	3,76	6,65	cointegrated
Netherlands	0	6	-1025,78	-	11,1051^{*1*5}	15,41	20,04	not cointegrated
Ireland	0	6	-898,99	-	18,08^{*1}	15,41	20,04	not cointegrated
Iceland	1	9	-851,12	0,47644	4,4327^{*1}	3,76	6,65	cointegrated
Israel	1	9	-946,97	0,34704	0,8110^{*1*5}	3,76	6,65	cointegrated
Italy	0	6	-1076,71	-	152060^{*1*5}	15,41	20,04	not cointegrated
Japan	0	6	-1431,03	-	13,1497^{*1*5}	15,41	20,04	not cointegrated
Luxembourg	1	9	-783,50	0,2373	3,2195^{*5}	3,76	6,65	cointegrated
Norway	1	9	-1071,74	0,26708	6,3863^{*1}	3,76	6,65	cointegrated
New Zealand	0	6	-865,05	-	14,5242^{*1*5}	15,41	20,04	not cointegrated
Portugal	1	9	-879,332	0,34076	2,5431^{*1*5}	3,76	6,65	cointegrated
United Kingdom	0	6	-1100,75	-	14,6881^{*1*5}	15,41	20,04	not cointegrated
Sweden	0	6	-1085,37	-	18,0756^{*1}	15,41	20,04	not cointegrated
Turkey	1	9	-1068,43	0,27259	0,0906^{*5}	3,76	6,65	cointegrated

* Significant value to the Trace statistic, at 1% and 5% vector number of cointegration (rank).
Source: Research data (2016).

Table 2 shows the existence of Johansen cointegration vectors for seven countries: Australia, Canada, Spain, Greece, Iceland, Israel, Luxembourg, Norway, Portugal and Turkey. The figure indicates the presence of univariate cointegration equations for the trace statistic (R = 1) when the maximum statistic is greater than their critical values of 5% and 1% (95% and 99% confidence). The existence of at least one long-term relationship and a balance linear combination between economic growth and CO_2 emission was confirmed. The estimation provides support for accepting H1 hypothesis that economic growth, represented by the total GDP, and the volume of CO_2 emissions are cointegrated. For the countries, the results were statistically significant for the absence of cointegration between the two variables.

The cointegration absence of the null hypothesis was accepted because the figures of cointegration vectors were zero for statistic trace test (R = 0) at a significance level of 1% and 5%. The results of non cointegration for most countries can be related to characteristics of variables under scrutiny, which are not in balance in the long term. When the R is equal to zero there is no cointegration vector. We carried out The Granger causality test using the VAR method, displayed in Table 3.

It is verified in Table 3 that the Granger causality test indicated ratio of bilateral cause for Greece and Turkey, suggesting that changes in the economic growth of these countries cause variations in CO_2 emissions, and CO_2 emissions also cause economic growth. There are signals of unilateral causal relationship between Australia, Belgium, Ireland, Israel and Japan, where increased economic growth, cause increases in CO_2 emissions. It has been found evidence of unilateral causal relationship to Canada and Finland, to the increase in CO_2 emissions, causing an increase in economic growth.

The links between CO_2 emissions and economic growth are not in balance in the long run for countries with no cointegration (Table 2) and the presence of causality (Table 3), but these relationships occur in the short term for Belgium, Finland and Japan. Any long-term incentive policy for these countries may be ineffective and short-term measures are indicated (up to 5 years). One of the measures to be used is the replacement of the logistic chain fuel for alternative sources, such as biodiesel. Other ways to reduce CO_2 emissions is to adopt a shared logistics network and the creation of logistics warehouses in relevant points [13]. This contributes to the preservation of road infrastructure of the countries, which may affect the increase or decrease in the volume of CO_2 emissions. Alternative measures such as combating deforestation, use of electric vehicles and encouraging the use of public transport could be used.

Table 3. Granger causality test

Countries	Equation	Excluded	Chi²	Df	Prob>Chi²	Result
Australia	co_ australia	cr_ australia	5,2261	2	0,073	Causality*
	cr_ australia	co_ australia	1,7456	2	0,418	No Causality
Belgium	co_belgium	cr_ belgium	7,6457	2	0,022	Causality
	cr_ belgium	co_belgium	0,2878	2	0,866	No Causality
Canada	co_canada	cr_canada	0,68979	2	0,708	No Causality
	cr_canada	co_canada	4,928	2	0,085	No Causality
Denmark	co_denmark	cr_denmark	2,3503	2	0,309	No Causality
	cr_denmark	co_denmark	0,44441	2	0,801	No Causality
Spain	co_spain	cr_spain	3,4814	2	0,175	No Causality
	cr_spain	co_spain	1,7756	2	0,412	No Causality
U.S	co_usa	cr_usa	1,4888	2	0,475	No Causality
	cr_usa	co_usa	1,6321	2	0,442	No Causality
Finland	co_finland	cr_ finland	3,7092	2	0,157	No Causality
	cr_ finland	co_ finland	12,368	2	0,002	Causality
France	co_france	cr_ france	4,4496	2	0,108	No Causality
	cr_ france	co_ france	3,0369	2	0,219	No Causality
Greece	co_greece	cr_ greece	18,099	2	0,000	Causality
	cr_ greece	co_ greece	5,038	2	0,081	Causality*
Netherlands	co_netherlands	cr_ netherlands	0,49232	2	0,782	No Causality
	cr_ netherlands	co_ netherlands	1,5898	2	0,452	No Causality
Ireland	co_ireland	cr_ ireland	13,737	2	0,001	Causality
	cr_ ireland	co_ ireland	4,4342	2	0,109	No Causality
Iceland	co_iceland	cr_ iceland	3,6574	2	0,161	No Causality
	cr_ iceland	co_ iceland	2,525	2	0,283	No Causality
Israel	co_israel	cr_ israel	8,4652	2	0,015	Causality
	cr_ israel	co_ israel	0,26664	2	0,875	No Causality
Italy	co_italy	cr_ italy	0,02627	2	0,987	No Causality
	cr_ italy	co_ italy	4,2585	2	0,119	No Causality
Japan	co_japan	cr_ japan	7,1322	2	0,028	Causality
	cr_ japan	co_ japan	3,2006	2	0,202	No Causality
Luxembourg	co_luxembourg	cr_ luxembourg	1,8159	2	0,403	No Causality
	cr_ luxembourg	co_ luxembourg	0,91457	2	0,633	No Causality
Norway	co_norway	cr_ norway	1,1442	2	0,564	No Causality
	cr_ norway	co_ norway	0,59202	2	0,744	No Causality
New Zealand	co_newzealand	cr_ newzealand	2,1374	2	0,343	No Causality
	cr_ newzealand	co_ newzealand	0,1061	2	0,948	No Causality
Portugal	co_portugal	cr_ portugal	4,5876	2	0,101	No Causality
	cr_ portugal	co_ portugal	1,6123	2	0,447	No Causality
United	co_unitedKingdo	cr_unitedKingdo	1,82338	2	0,402	No Causality
Kingdom	cr_united|kingdo	co_unitedkingdo	1,1909	2	0,551	No Causality
Sweden	co_sweden	cr_sweden	3,6734	2	0,159	No Causality
	cr_sweden	co_sweden	3,122	2	0,210	No Causality
Turkey	co_turkey	cr_turkey	8,6521	2	0,013	Causality
	co_turkey	co_turkey	6,9737	2	0,031	Causality

*Cause at the significance level of 0.10
Source: Research data (2016).

For countries with cointegration and causality confirmed such as Australia, Canada, Greece, Israel and Turkey, the long-term measures are more effective. These countries could create alternative strategies of political and economic nature, to reduce the volume of CO_2 emissions; however, such alternatives should not negatively impact the overall economic growth. As an alternative to reduce the volume of greenhouse gas emissions, countries like Finland have created environmental policies to reduce CO_2 emissions, such as supporting the use of nuclear and wind power, electricity import from Russia and Estonia [22]. The time series of the countries may have different characteristics that result in opposite directions of causality. Different causal directions require different economic policies and it is important to know their directions through the Granger causality test [20]. Causality found between CO_2 emissions and economic growth indicate particular characteristics of the countries, a good example is more lenient environmental legislation regarding the creation of new businesses without any impact monitoring in the environment.

Even if different countries adopt incentive measures to reduce the impact on the environment, they will act in order to slow down its effects, rather than its elimination. Eco-innovation could be an alternative to reduce the volume of emissions in countries that economic growth caused CO_2 emissions, such as Australia, Belgium, Ireland, Israel and Japan, for example. [4] found that changes in the regulations to the industrial and economic level and the presence of social regulatory elements, impacted the innovative development of the countries, offering space to combine emission reduction actions. Developing countries can learn based on environmental policies created by developed countries [20]. Environmental preservation can be balanced with economic growth if certain conditions are fulfilled [18].

As an alternative for better visualization of the countries that had cointegration and causality for the Johansen and Granger tests, Figure 2 shows that the areas of concentration where such relations were confirmed.

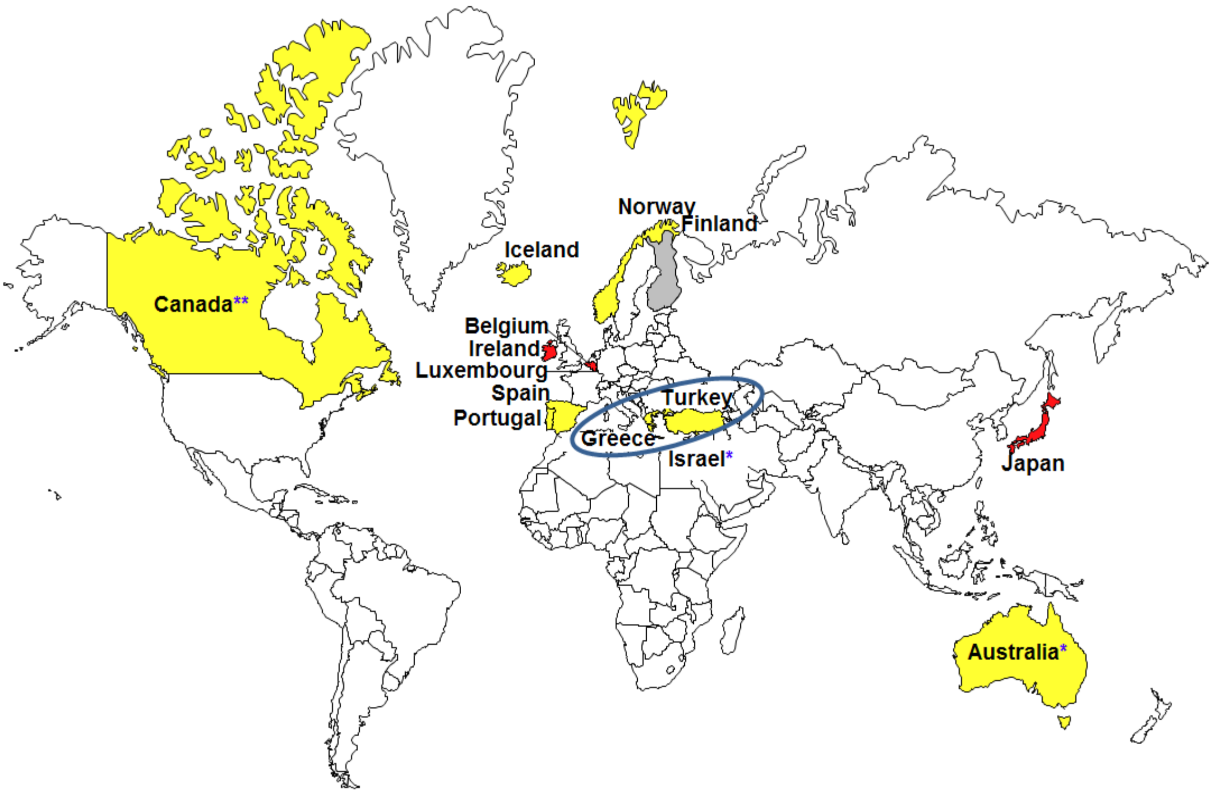

Figure 2. Countries with relations of cointegration and causality confirmed

Caption:
Yellow: Cointegration relations – Australia*, Canada, Spain, Greece, Iceland, Israel, Luxembourg, Norway, Portugal and Turkey.
Circle: cointegration relations and causality bilateral relationship: Greece and Turkey.
Red: economic growth causes CO_2 emissions: Australia*, Belgium, Ireland, Israel* and Japan.
Grey: CO_2 causes economic growth: Canada** and Finland.
*Cointegration and growth causes CO_2 emissions
**cointegration and CO_2 causes economic growth
Source: Research data (2016).

Figure 2 illustrates the concentration of European countries with unilateral causality between economic development and CO_2 emissions or between CO_2 emissions and economic growth. This concentration of European countries relates to the fact that the OECD was created in Europe and formed by many European countries. A desire shared by the countries is that economic growth can be a characteristic present in its development with adequate infrastructure to meet the demands of society and make it more attractive in terms of employment and income. As the economy develops and grows, it is more likely to increase its impact on the environment; however, since the country has reached the stage of growth and its domestic needs are met, it becomes easier to adopt additional measures to prevent the degradation of the environment.

Evidence of the cross country sample for the OECD countries showed no convergence among all the countries analyzed. This suggests that some long-term factors can interact with individual characteristics of each country, leading to different results. The results provide evidence to confirm the null hypothesis (H0) that economic growth and CO_2 emissions are not cointegrated for most OECD countries. For countries like Australia, Canada, Spain, Greece, Iceland, Israel, Luxembourg, Norway, Portugal and Turkey (H1) is accepted, since the series economic growth and CO_2 emissions are cointegrated. The results of the countries did not show convergence for the third and fourth hypothesis. For countries like Denmark, United States, France, Holland, Iceland, Italy, Luxembourg, Norway, New Zealand, Portugal, Sweden and the UK there were sufficient evidence to confirm H2; economic growth and CO_2 emissions do not have causal relationships. The third hypothesis was validated when economic growth and CO_2 emissions have causal relationships for Australia, Canada, Greece, Israel, Japan and Turkey.

In Appendix A, the variable behavior is visualized for the 22 countries over 50 years, illustrated by graphs. The exhibition graphics occurred in order to verify the behavior of the series in the previous stage to receive the econometric treatment. In the countries analyzed, economic growth has evolved over the years and at one point there is a balance between the two time series, mainly by a decrease in CO_2 emissions occurred between the 1980s and 1990s. This behavior of the series may be linked to initiatives of international bodies to reduce greenhouse gases. In Luxembourg it was through the work of the Intergovernmental Panel on Climate Change (IPCC) adopted by the country in 1990 [2].

Countries like Australia, USA, Spain, Greece, Holland, Ireland, Israel, Italy, New Zealand, Portugal and Turkey presented a slight increase in the volume of CO_2 emissions, following increases in economic growth. A peculiar fact is that Greece and Italy have shown higher emissions rates compared with other countries. Countries such as Portugal, for example, adopted initiatives undertaken by the European Union (EU) to reduce emissions of CO_2 [16]. In New Zealand this result may be related to deforestation that took place in the country [8] and Turkey coming largely (86%) with the development of the energy sector [21].

5. CONCLUSION

This study aimed to determine whether there is relationship of cointegration and causality between economic growth and CO_2 emission levels in 22 member countries of the OECD. We found statistically significant evidence that the series economic growth and CO_2 emissions, are in balance in the long run in ten countries, namely Australia, Canada, Spain, Greece, Iceland, Israel, Luxembourg, Norway, Portugal and the United Kingdom. A linear combination of long-term relationships and balance between the variables of these countries was identified. Thus, the results confirmed the first hypothesis that economic growth and CO_2 emissions are cointegrated for Australia, Canada, Spain, Greece, Iceland, Israel, Luxembourg, Norway, Portugal and the United Kingdom. Because of differences their cointegration was not confirmed for the other countries, and thus accepting the null hypothesis that economic growth and CO_2 emissions are not cointegrated.

From the point of view of causality, the results showed bilateral relationship to Greece and Turkey, suggesting that variations in economic growth cause CO_2 emissions and CO_2 emissions also cause economic growth. Other countries in which this relation was confirmed showed unilateral causal characteristics between growth and CO_2 emissions, namely, Australia, Belgium, Ireland, Israel and Japan. This unilateral causal relationship was confirmed for Canada and Finland indicating that the increase in CO_2 emissions causes an increase in economic growth. The causal direction occurs in one direction, so the results provide support to confirm the third hypothesis that economic growth and CO_2 emissions have causal relationships. Whereas in some countries this relationship has not been confirmed, it is accepted the second hypothesis that economic growth and CO_2 emissions do not have any causal relationships.

The results of causality between CO_2 emissions and economic growth may indicate the need for the creation of alternative political and economic strategies that will reduce the volume of CO_2 emissions, however, with the opposite impact on economic growth per capita. This study points to short and long-term management implications that could be undertaken by the rulers of the countries. The adoption of short-term CO_2 emission reduction actions could be taken to countries such as Belgium, Finland and Japan in adopting anti-deforestation measures, the use of electric vehicles, heavy goods vehicles integrated into a network, and the use of public transport. Eco-innovation could also be an alternative to curb the volume of emissions in the countries in which economic growth caused CO_2 emissions. Countries could encourage the innovative potential of the companies in the use of cleaner technologies. Companies could also adopt ways that contribute to sustainable development and environmental social responsibility [15]. Long-term managerial implications could be adopted by governments of Australia, Canada, Greece, Israel and Turkey, related to the creation of reforestation areas, the use of clean energies such as wind, nuclear, solar, and the capture and underground disposal of CO_2.

From these results, it was concluded that there is evidence of long-term relationships and causality between economic growth and CO_2 emissions. This article offers three main contributions. The first is the use of variables GDP and CO_2 emissions for the cointegration and causality analysis, unlike other studies using variables such as productivity, population income and energy consumption. The second contribution is to analyze the behavior of variables from a time series comprising the 50 years, a time period longer than the study of [11], [12], [6] and [7]. The third contribution is the investigation of the relations of cointegration and causality in the countries of the OECD, indicating from the econometric analysis information about cointegrated series and relations of cause in the increase in CO_2 emissions.

Future studies could investigate the behavior of CO_2 emissions combined with environmental legislation variables in order to determine whether more lenient laws could have a greater propensity to CO_2 emissions, driven by lower restrictions on the creation of new businesses, which could become polluters. Because of the results found for Finland, which reduced its CO_2 emissions by importing energy from Russia and Estonia, future studies could verify that countries that sell its energy or receiving multinational companies from other countries had an increased emission of greenhouse gases. This study was limited to examining the OECD member countries, thus further investigations could be carried out in other countries, such as South America and Africa to see how this relationship occurs with the dynamics of these countries.

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Dokazi međusobnih zemalja o odnosima u vezi sa kointegracijom i uzročnosti između ekonomskog rasta i emisija CO2 u zemljama OECD-a

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Primljen (06.09.2017.); Recenziran (08.11.2017.); Prihvaćen (10.01.2018.)

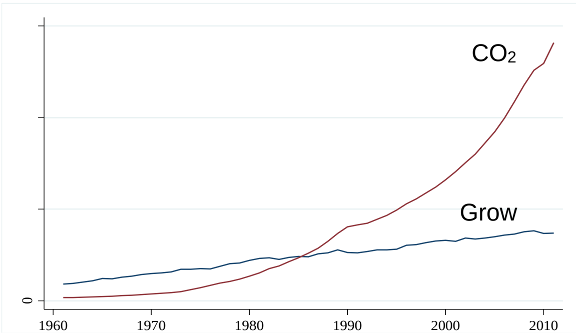
Apstrakt

Ovaj članak ima za cilj potvrđivanje postojanja odnosa kointegracije i uzročnosti između ekonomskog rasta i emisije CO_2 u 22 zemlje članice OECD-a, u vremenskom intervalu od 1961. do 2011. godine. Rezultati pokazuju da su ekonomski rast i CO_2 dugoročno u ravnoteži za deset zemalja. Test kauzalnosti pokazao je bilateralni odnos, što ukazuje da varijacije u ekonomskom rastu izazivaju emisije CO_2, kao i da emisije CO_2 izazivaju ekonomski rast. Duge i kratkoročne alternativne mere, kao što su pošumljavanje, borba protiv smanjivanja šuma, upotreba energije vetra, nuklearne i solarne energije, električnih vozila, podsticaja za korištenje javnog prevoza, sakuplanje i skladištenje CO_2 preporučuju se zemljama kod kojih CO_2 izaziva ekonomski rast. Stoga se zaključuje da postoje dokazi o dugoročnim i uzročnim odnosima između ekonomskog rasta i emisije CO_2.

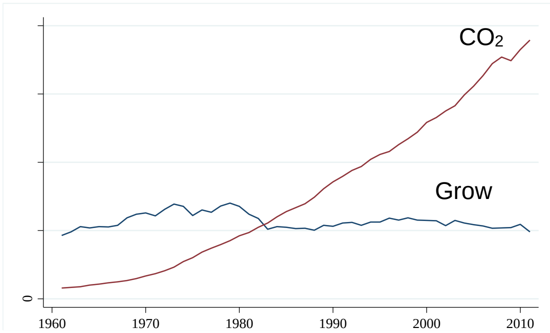
Ključne reči: *Ekonometrija, zemlje OECD-a, održivost, vremenske serije*

Appendix A - Evolution of CO2 emissions and economic growth * (1961-2011)

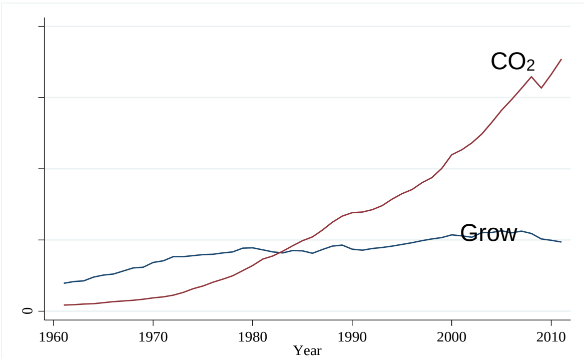
Graph 1 - Australia



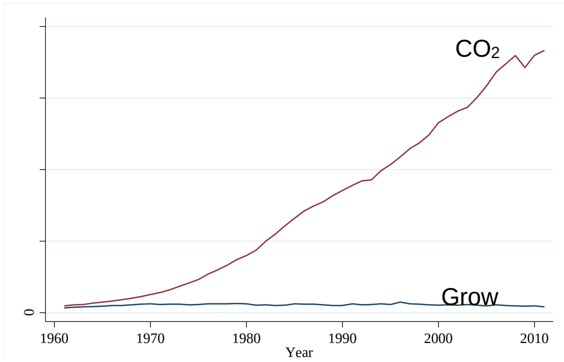
Graph 2 – Belgium



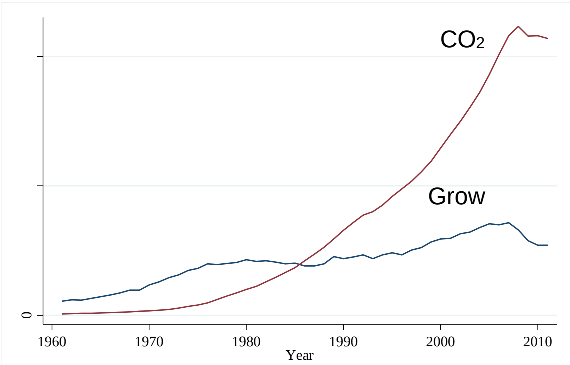
Graph 3 – Canada



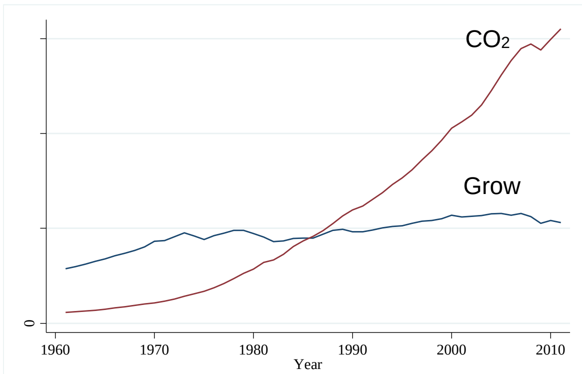
Graph 4 – Denmark



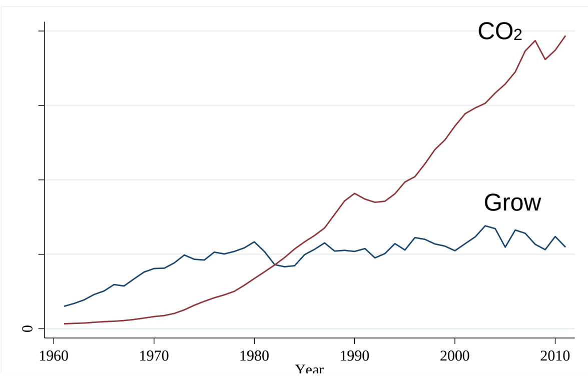
Graph 5 - Spain



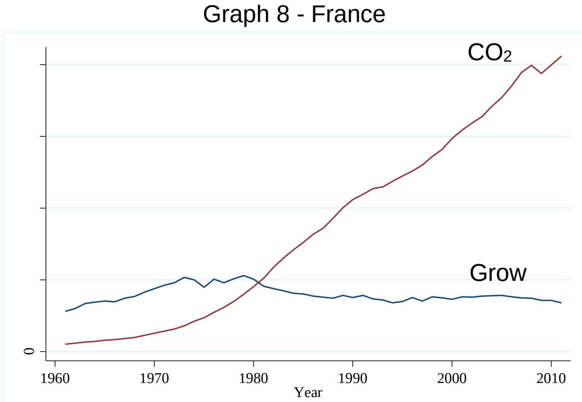
Graph 6 - United States



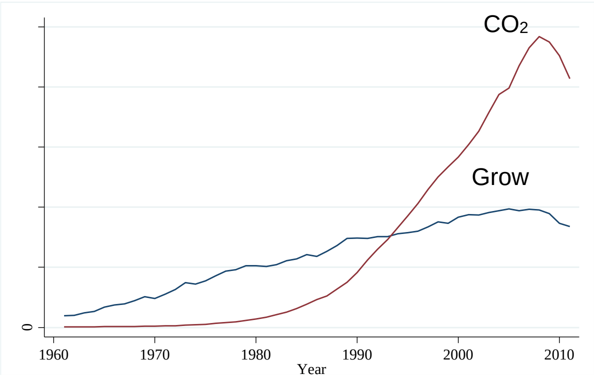
Graph 7 – Finland



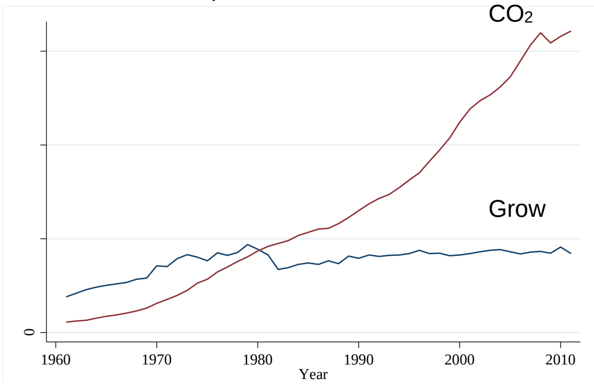
Graph 8 - France



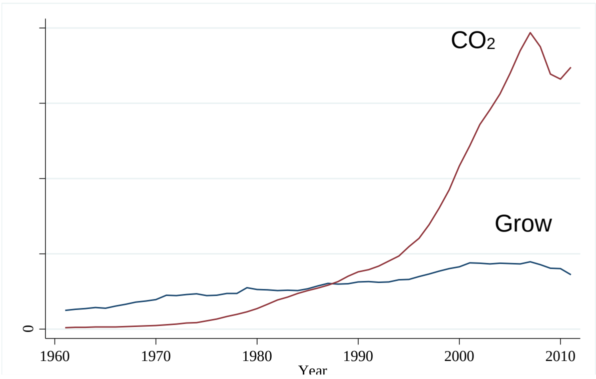
Graph 9 – Greece



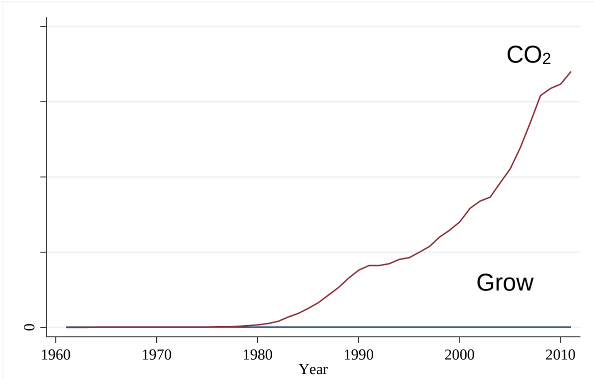
Graph 10 – Netherlands



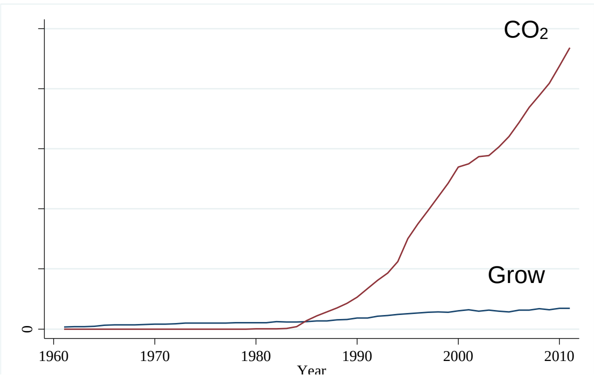
Graph 11 - Ireland



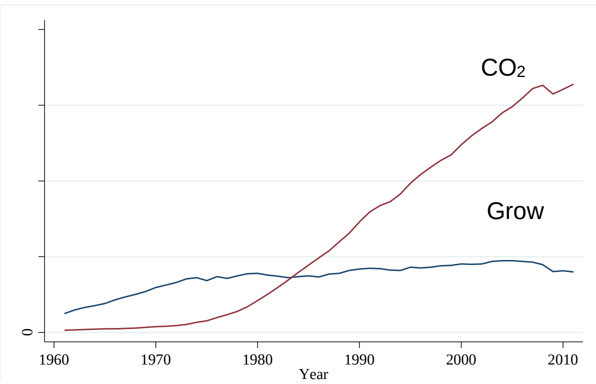
Graph 12 – Iceland



Graph 13 - Israel



Graph 14 - Italy



Graph 15 – Japan

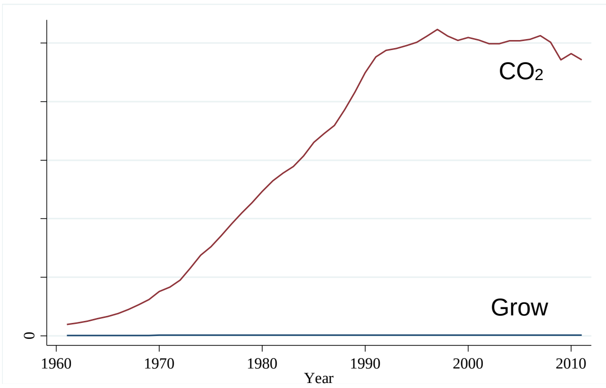
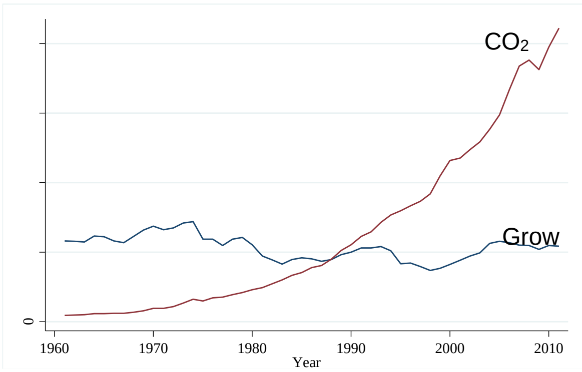
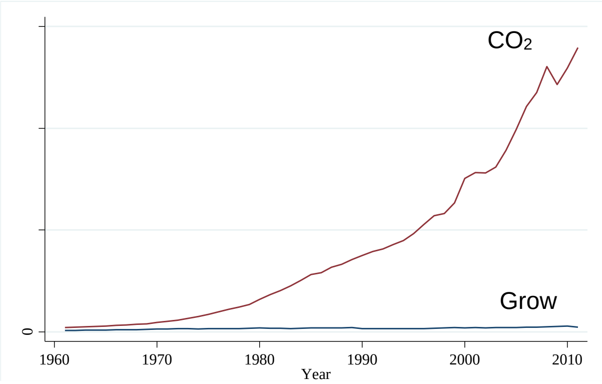


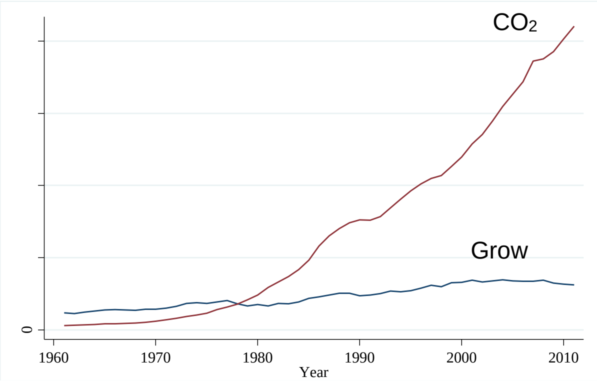
Chart 16 – Luxembourg



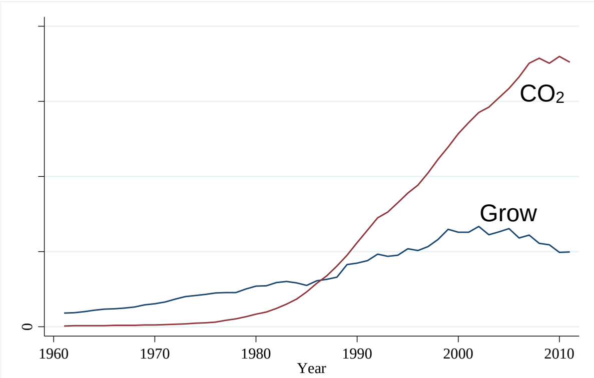
Graph 17 – Norway



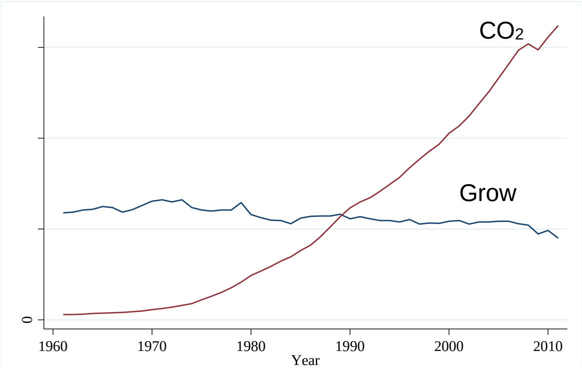
Graph 18 - New Zealand



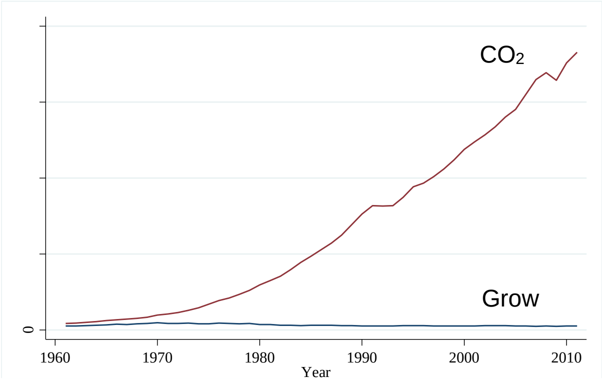
Graph 19 – Portugal



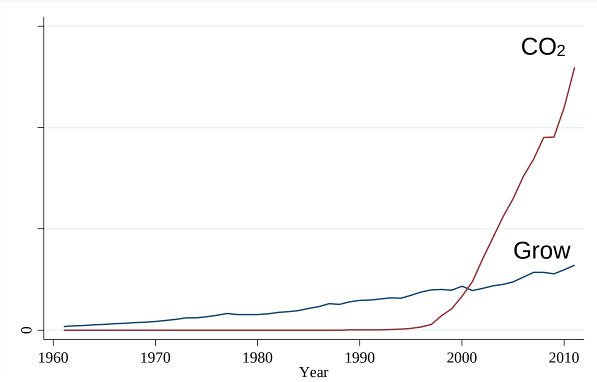
Graph 20 - United Kingdom



Graph 21 - Sweden



Graph 22 - Turkey



* Economic growth represented in units of millions of reais (Real value divided by 100,000,000).