GDP per capita and greenhouse gas emissions in Europe

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22 June 2022

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Resumen: Un candente debate durante los últimos años gira en torno a que nuestras economías se basan en el consumo de recursos naturales y hasta qué punto debemos priorizar el crecimiento económico en lugar de sacrificarlo en beneficio del medio ambiente. Para analizar esta problemática compararemos las emisiones de efecto invernadero de una variedad de países europeos con el PIB per cápita de esos países para analizar la relación entre estas dos variables.

Abstract: A hot debate during the last years is going around the fact that our economies are based on natural resources consumption and up to which extend should we prioritize economic growth instead of sacrificing it in benefit of the environment. To analyze this problematic we will compare the greenhouse emissions of a variety of European countries with the GDP per capita of those countries to analyze the relationship among these two variables.

JEL classification: Q01, Q50

1. Introduction and motivation:

During the last years it has not been clear how to assess the contribution of each country to the major purpose of reducing greenhouse gas emissions all over the world to avoid global warning (Belloc et al., 2022). Commuting is an activity which contributes to this kind of emissions (Giménez et al., 2015, 2016, 2018, 2019, 2020, 2021, 2022), with green mobility being a clear objective around the word (Echeverría et al., 2021, 2022; Giménez et al., 2019, 2021; Molina et al., 2020).

In this study, I will delve in the analysis of the greenhouse gas emissions related with the GDP per capita in the euro zone using a clear and simple metric that I consider very fair and interesting at the time of obtain some insights about the conflictive relationship of environmental damge and economic growth. Greenhouse gas emissions in relation with the GDP per capita of a country are a measure that makes us able to study the eco-efficiency of an economy. In order to achieve a better future for everyone it is important to balance both variables in order to not hurt economic growth (and thus wellbeing of the citizens) but keeping an eye on which future are we leaving to those who follow us.

Greenhouse gas emissions by unit of GDP has the advantage of being a simple metric understandable by anyone that serves to illustrate the performance of each country in ecological terms but without falling on fallacies that does not take into account the particular circumstances of each country. In this way, we can have a tool that takes into account not only the absolute figure of greenhouse gas emissions but also the level of income of the average person for a society. This tool will allow us to understand in which phase of development a country is and what can be expected in the upcoming years for that country depending on their current situation.

It is important to assume that not every increase in the economic activity of a country will have a similar repercussion on the greenhouse gas emissions. The economic framework has a lot of ramifications that allows multiplying or diluting the changes of a variable or another into the economy.

The remaining study is organized as follows. Section 2 discusses analogous studies while Section 3 presents the methodology adopted. Section 4 provides a discussion of the data used and Section 5 is dedicated to present and discuss the obtained results. Finally, the Section 6 serves as a conclusion.

2. Review of the literature

Global warming and economic growth have been in the center of the debate during the last years of even decades, and it is impossible to make efficient and fair rules that allow us to solve this dilemma if we do not understand the nature of the problem.

In this scenario, a lot of economists have tried to shed some light on the matter, but most of the times giving us opposite conclusions. In the last years, the discoveries of Beckerman suggested that in early stages, economic growth would lead to environment degradation, but in latter stages, would be the opposite, what should encourage nations to become richer in order to avoid both problems (Beckerman, 1992).

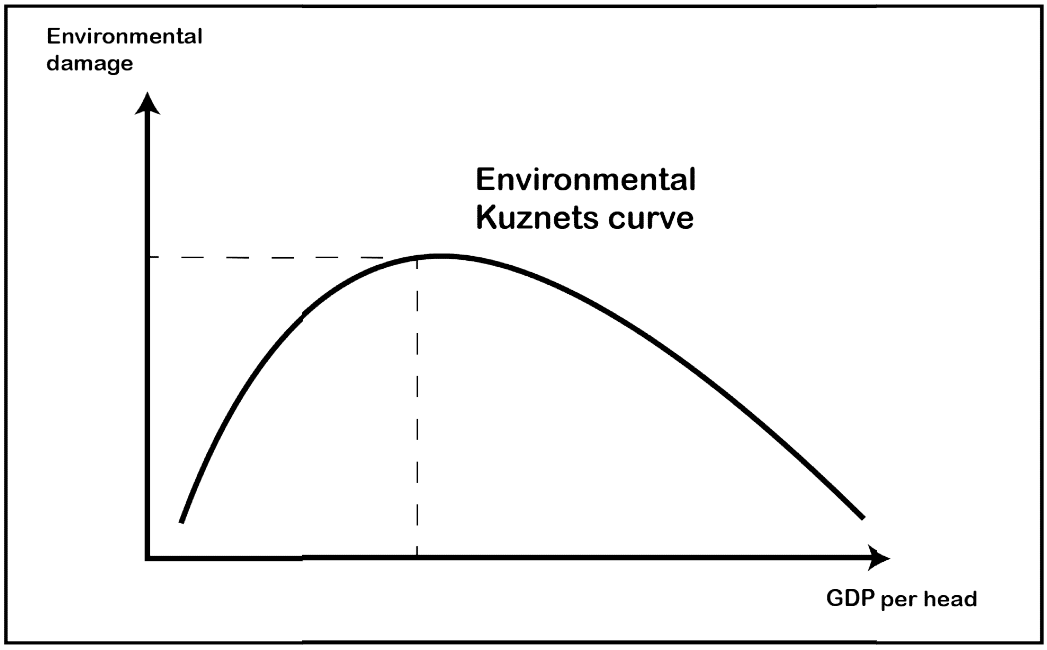
However, in 1995, Arrow (Arrow, 1995) concluded that actually the reality was not so simple. The relationship between both variables would depend on more specific circumstances that are never possible to generalize.

A point that sustains Beckerman´s theory is the fact that economic growth is often bounded to technological innovations that tends to increase the efficiency of the process, leading to reductions in the needs for raw materials that are related with greenhouse gas emissions.

Also, the predominance of the service sector tends to grow as the acquisition level is also higher, which would mean that economic growth could happen without damaging the environment via greenhouse gas emissions. Another point is that given a high level of income, citizens would prefer to consume products made through more ecological processes, which does not sound crazy given the prices of most of the biological products in comparison to the traditional ones.

An important concept related to Beckerman discoveries is the Kuznets Environmental Curve, which sustains that in early stages of economic development emissions will increase but just until a point in which income reaches a level that allows emissions to decrease. Curiously, the Environmental Kuznets Curve was not directly discovered by Simon Kuznets, in fact, his main discovery was the Kuznets Curve (Kuznets, S. 1955), which explains that there is a point in the economic development of a country since which the income inequality tends to reduce.

Starting from this important contribution to the economic science, other authors adopted new ways and optics for economic research. In 1994 (Selden & Song. 1994) tested for the existence of en environmental Kuznets curve. They concluded that most of the countries have not exceeded the threshold since where pollution starts to decline, so emissions would probably increase in the next years. However, they discovered that accelerated economic growth can have an important positive effect on the reduction of pollution, being population density another factor that helps on accelerating the process.



Source: Self-elaborated

Some authors (Hettige et al., 2000) analyzed international data and observed that the share of the industrial sector in respect with the national production fits with the concept of the Kuznets environmental curve, but not other determinant factors such as the participation of the polluting sectors on national industry or pollution intensity per unit of product in those industrial and polluting sectors.

Later, other authors (Apergis & Payne., 2009) demonstrated that in the long-run, energy consumption has a positive statistical transmission into emissions. But on the other hand, real production showed a pattern that fits perfectly with the environmental Kuznets curve showed above.

3. Methodology, data and variables

To study the correlation between greenhouse gas emissions and GDP per head, we are going to follow a descriptive statistical analysis. The objective is to get some measures, graphics and charts that truly represent the reality of the environmental awareness. Some of the measures that we are going to use are predictions, means, ratios and evolution of variables.

The data used comes from the World Development Indicators (World Bank database) and we have data for 11 European countries from 1971 to 2018. The data is for greenhouse gas emissions and GDP per capita in constant 2015 dollars (deflacting GDP).

Since this data, we are going to analyze by individual countries and by groups of countries (for example; Mediterranean ones), trying to find any common pattern depending on the geographical location, culture or other circumstances. We are going to calculate some basic statistics, for example: Average GHG emissions, average GDP per capita, average GHG by each unit of GDP per capita (eco-efficiency of an economy), variation in GHG emissions during the last 47 years and the variation on GDP pc in the same period.

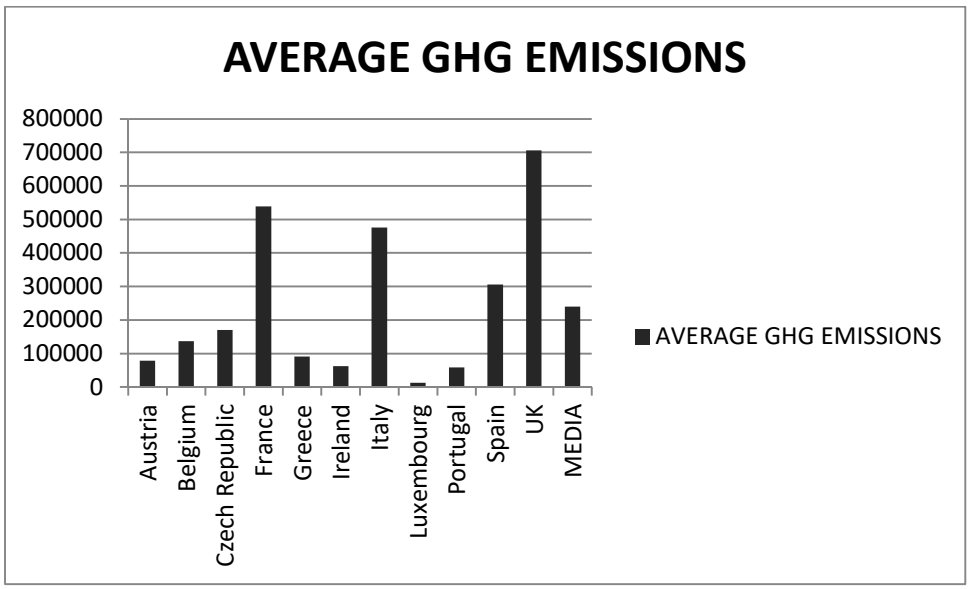
In addition, we are going to test if it is likely the hypothesis of the environmental Kuznets curve and in which cases of the sample it has a bigger impact. This should give us a clue on which path will follow the European economy in relation to the environmental damage.

Another interesting point will be to study which is the global pace in terms of eco-efficiency that the euro-zone as a whole is following to analyze if the global previsions for this economic block are going to be positive for both the environment and the economic growth.

Those analysis are going to be done taking into account not only the group of Mediterranean and non-Mediterranean countries but also the fact of the GDP pc related to the median of the sample. In that way, we are going to analyze if there are significant differences in the ecological performance of the countries and in their previsions depending on their level of income, both during the studied period and since 1971,

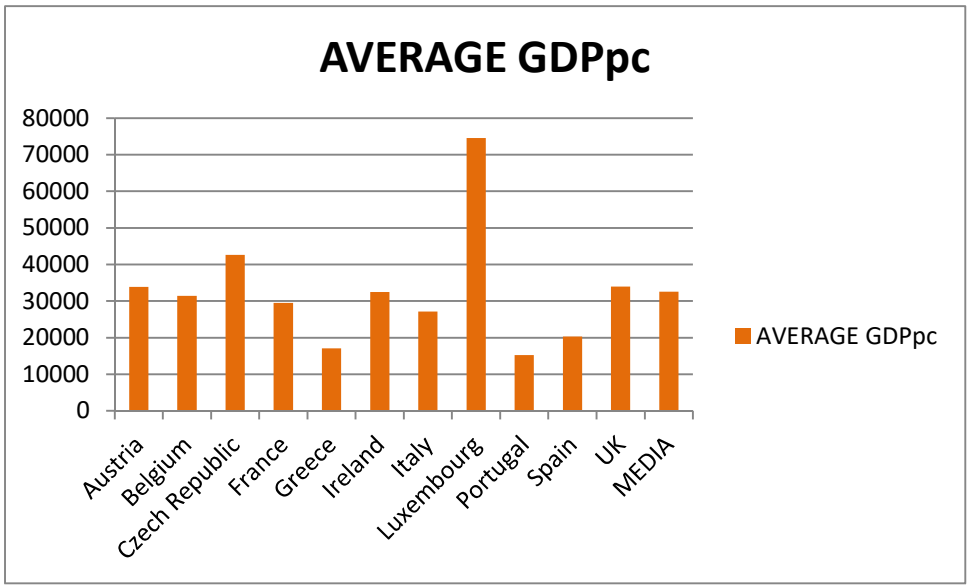
which will serve as a way to take into account the initial circumstances of each country and its evolution depending on those circumstances.

Figure 1: Average greenhouse gas emissions since 1971 to 2018.



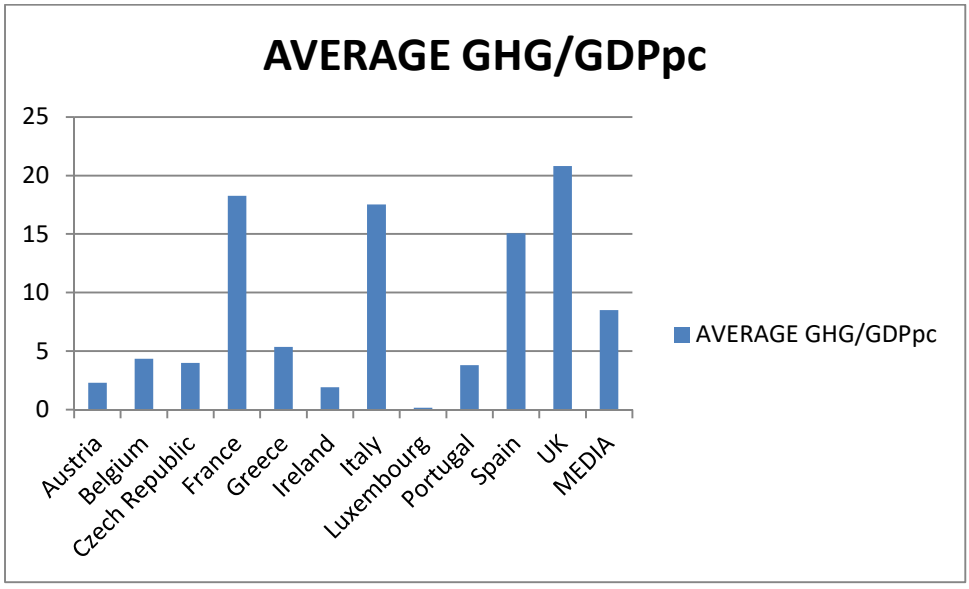
Data source: Development Indicators (World Bank database)

Figure 2: Average gross domestic product per capita since 1971 to 2018.



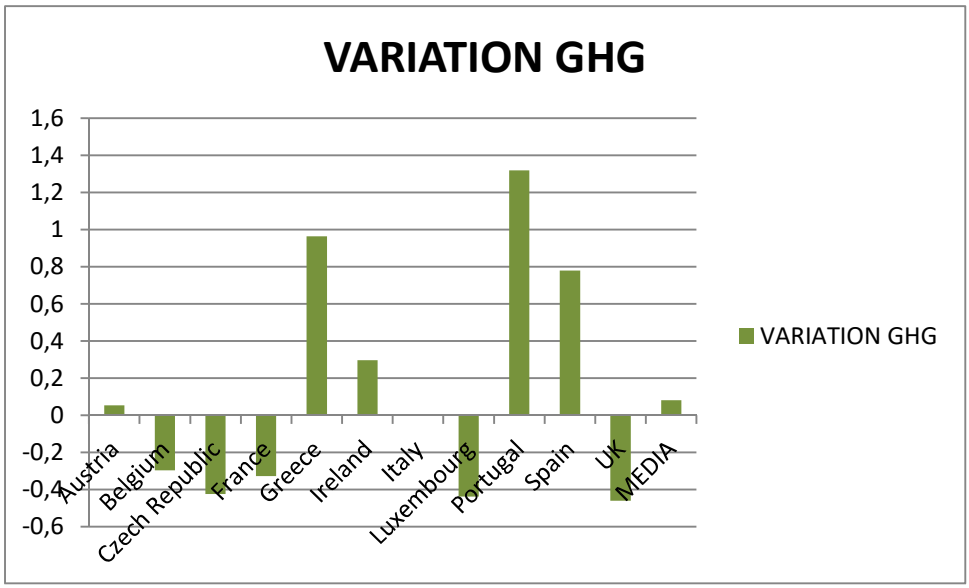
Data source: Development Indicators (World Bank database)

Figure 3: Average gross GHG by each unit of GDP per capita since 1971 to 2018.



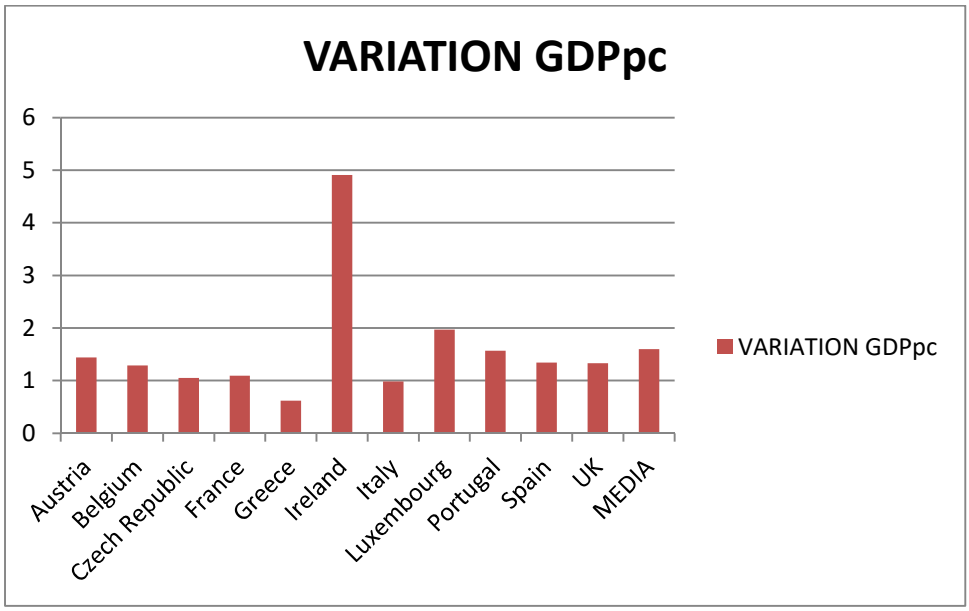
Data source: Development Indicators (World Bank database)

Figure 4: Variation in greenhouse gas emissions since 1971 to 2018.



Data source: Development Indicators (World Bank database)

Figure 5: Variation in GDP per capita since 1971 to 2018.



Data source: Development Indicators (World Bank database)

The graphs above, gives us a panoramic view of which are the countries with a better performance in terms of GDP per capita and GHG emissions, being Luxembourg the country with a higher efficiency in environmental impact terms, it has the greatest GDP per capita and the lower greenhouse emissions of the sample. It is also worth signaling that Ireland is the country with a higher growth in GDP terms, in fact, the country has almost multiplied by 5 times its GDP from 1971 to 2018. Also, Ireland exemplifies that economic growth is not incompatible with emissions control, despite being the country with the biggest growth, its greenhouse gas emissions are lower than those of countries like Spain, Greece of Portugal that have also increased their emissions but not growing at the same rate.

It is also important to highlight the low performance of countries such as Spain, Portugal or Greece, that besides being the countries with a higher capacity to substitute fossil fuels energy sources (the main source of greenhouse gas emissions) for solar energy, are the ones that have experienced a sharper growth on GHG emissions. It is also interesting to look to the evolution of these variables over time for the different countries, apart of the graphs showing the evolution of GHG emissions and GDP per country (that can be found on appendix A); we are going to focus on the evolution of emissions per unit of GDP per capita.

Another interesting metric is the correlation coefficient between greenhouse gas emissions and GDP pc. The correlation coefficient serves to study whether two variables are binded among them and the movement of one of those variables depends on the movements of the other. In the case of our study, we are going to focus on the European average rather than into specific countries (which behavior can be easily observed in individual graphs that plots GDP pc and GHG emissions).

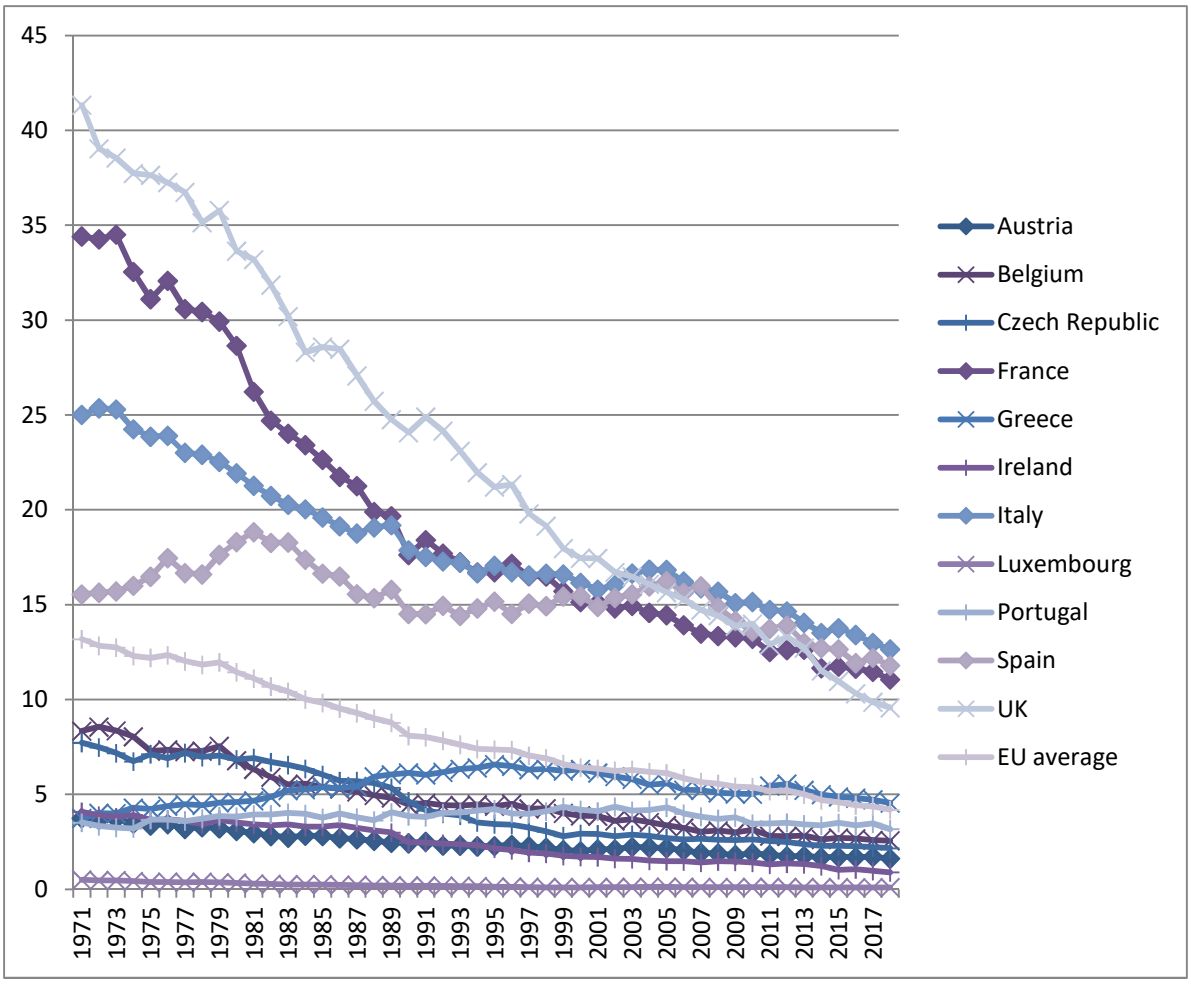
Table 1: Correlation coefficient between GHG emissions and GDP per capita.

Austria	0,499453783
Belgium	-0,876275068
Czech Republic	-0,912539269
France	-0,909131557
Greece	0,858276352
Ireland	0,741752686
Italy	0,536272535
Luxembourg	-0,642920057
Portugal	0,94734023
Spain	0,899949125
UK	-0,900441418
EU average	-0,578163633
Mediterranean countries	0,376377862
Non-Mediterranean countries	-0,926081191
Poorest countries	0,320069505
Richest countries	-0,927521236

Data source: Development Indicators (World Bank database)

In the case of the European average, the correlation coefficient for this period gives us a value of -0,578163633, which means that on average, by each unit the eurozone grows into GDP, there is 0.57 units of emissions that are reduced. Given the previous correlation coefficient, we could state that the GDP per head can explain on average a 32.5% of the European emissions. It is important to pay attention to the negative symbol, that indicates that the relationship is negative, so when economic growth occurs, it leads to a reduction in the level of emissions, which would lead to a more eco-efficient economy.

Figure 17: Evolution of GHG emissions by unit of GDP pc since 1971 to 2018.

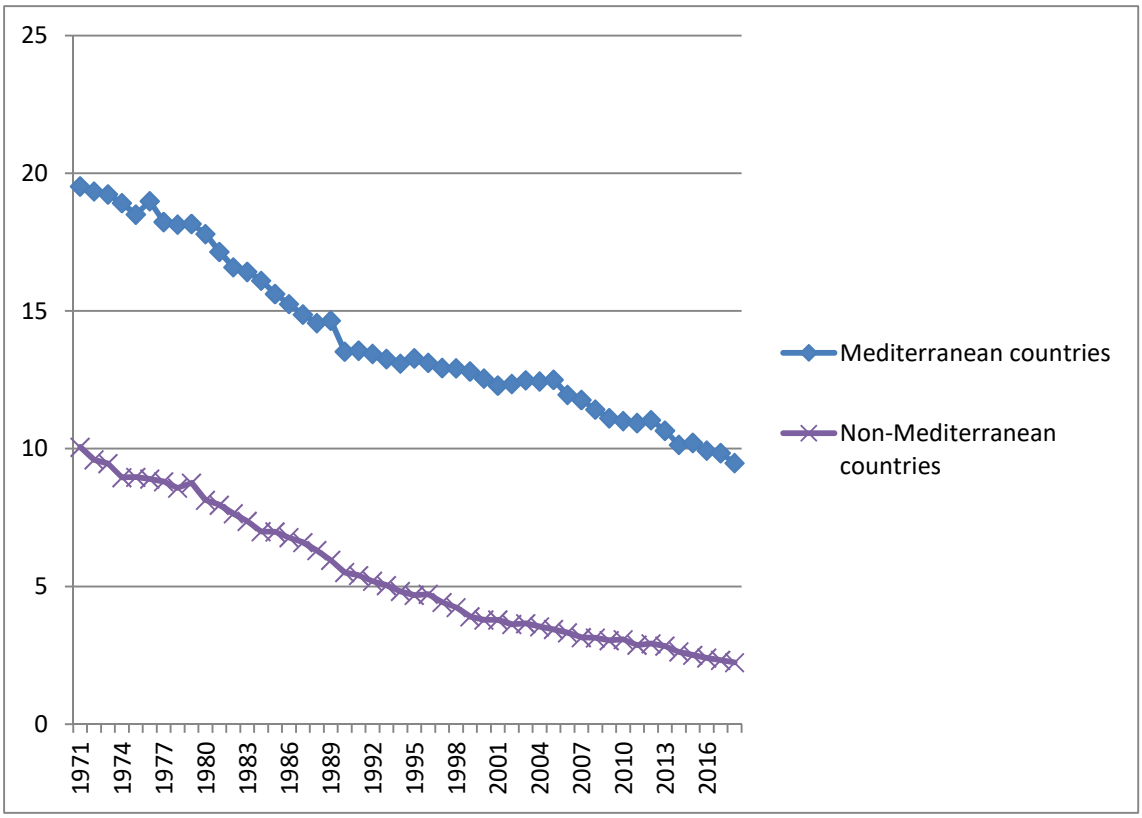


Data source: Development Indicators (World Bank database)

Looking the graph above, we could conclude that in general, the whole euro zone is converging to a higher level of eco-efficiency in their economies.

On the other hand, it is also interesting to evaluate this metrics by groups of countries. If we look at the graph below, we can extract the conclusion that the only difference between this two groups is on the starting point, since the slope of the decreasing curve is extremely similar.

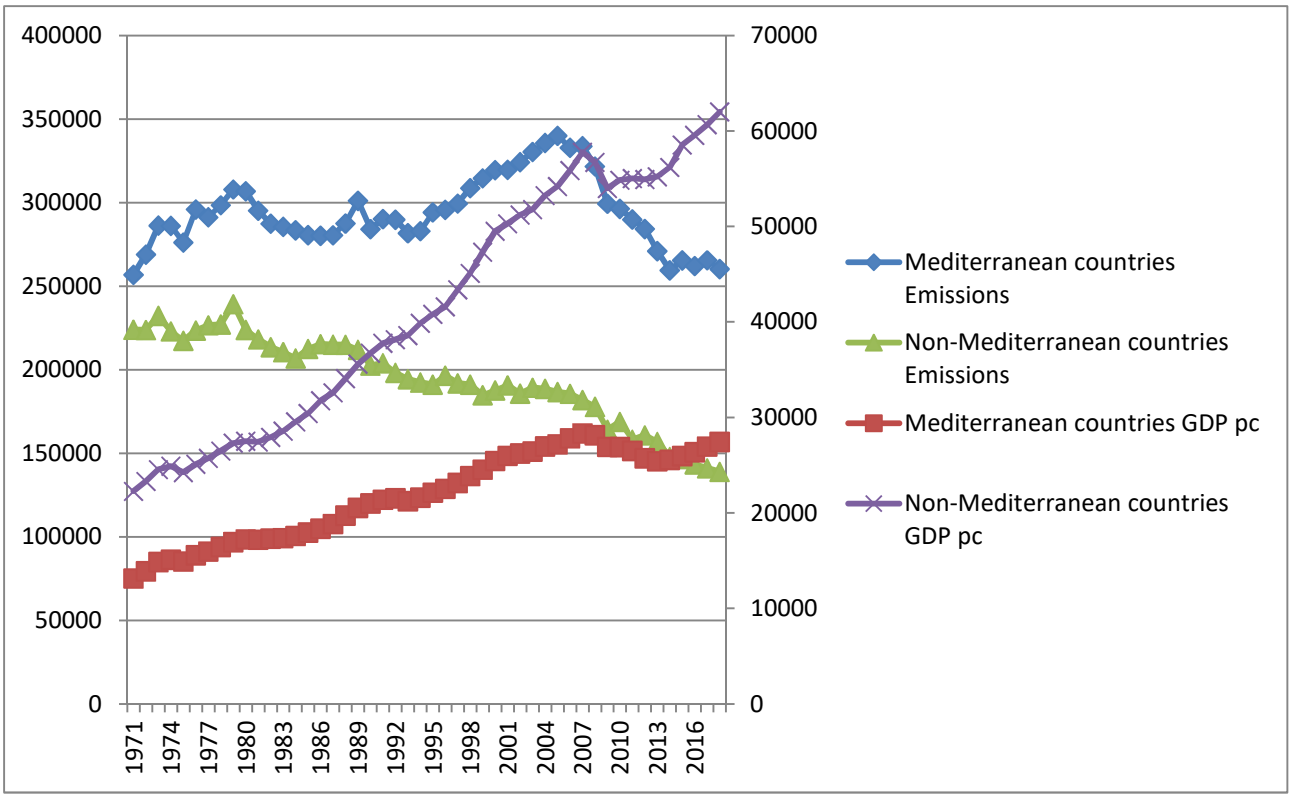
Figure 18: Evolution of GHG emissions by unit of GDP pc since 1971 to 2018.



Data source: Development Indicators (World Bank database)

However, if we look to the evolution of emissions and GDP pc on absolute terms instead of relative ones, we may observe that Mediterranean did not reduce the total level of emissions since 1971 while non-Mediterranean countries have. Also, the growing slope of the non-mediterranean countries is greater than the one of Mediterranean countries. So it is accurate to affirm that non-Mediterranean countries had a better performance since 1971 to 2018 since they have grown at a greater pace than Mediterranean countries while they have decreased their total level of emissions. This seems like a lost opportunity for Mediterranean countries, since most of the greenhouse gas emissions comes from the fuel burning directly linked to energy generation that in the case of this countries could be easily substituted by solar energy.

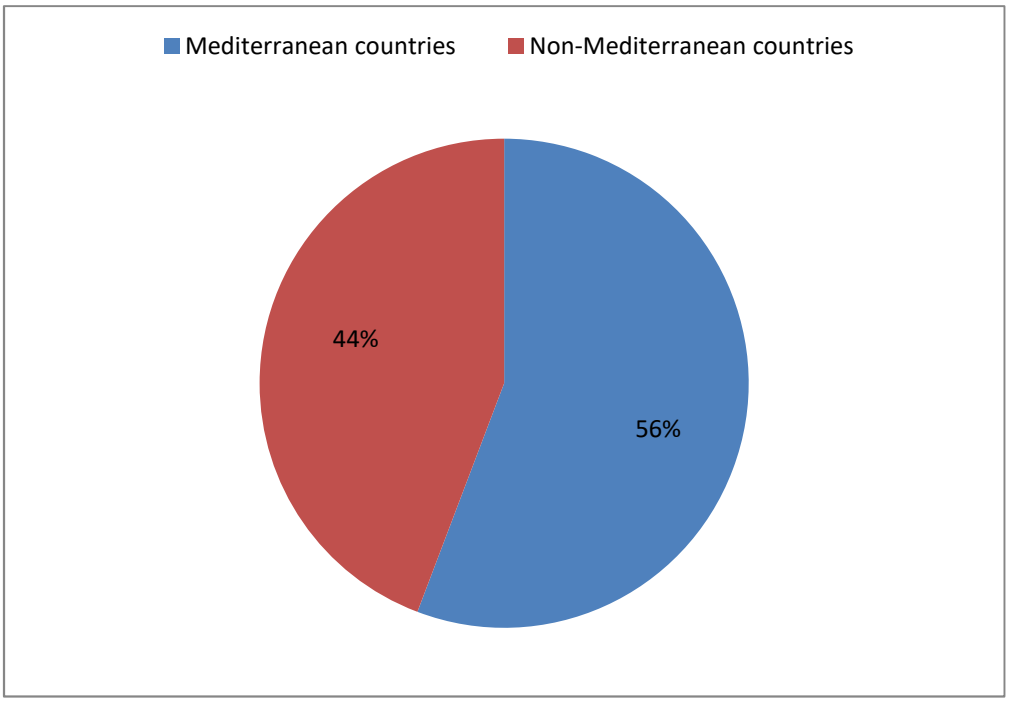
Figure 19: Evolution of GHG emissions and GDP pc since 1971 to 2018.



Data source: Development Indicators (World Bank database)

In fact, and as can be seen in figure 10 below, 56% of the average emissions in all the studied sample during the selected period comes from the Mediterranean countries while 40% comes from the non-Mediterranean countries (even when Mediterranean countries represented 45% of our sample). The positive aspect is that Mediterranean countries still have a great margin of growing for their economies while reducing their GHG emissions.

Figure 20: Share of the total GHG emissions by countries from 1971 to 2018.



Data source: Development Indicators (World Bank database)

Another important topic in this research is to analyze up to which extent is feasible the hypothesis of environmental Kuznets curve, that, as explained in section 3, is characterized by a U shape, indicating an increase of greenhouse gas emissions during early stages of economic growth but a decreasing pace during later epochs.

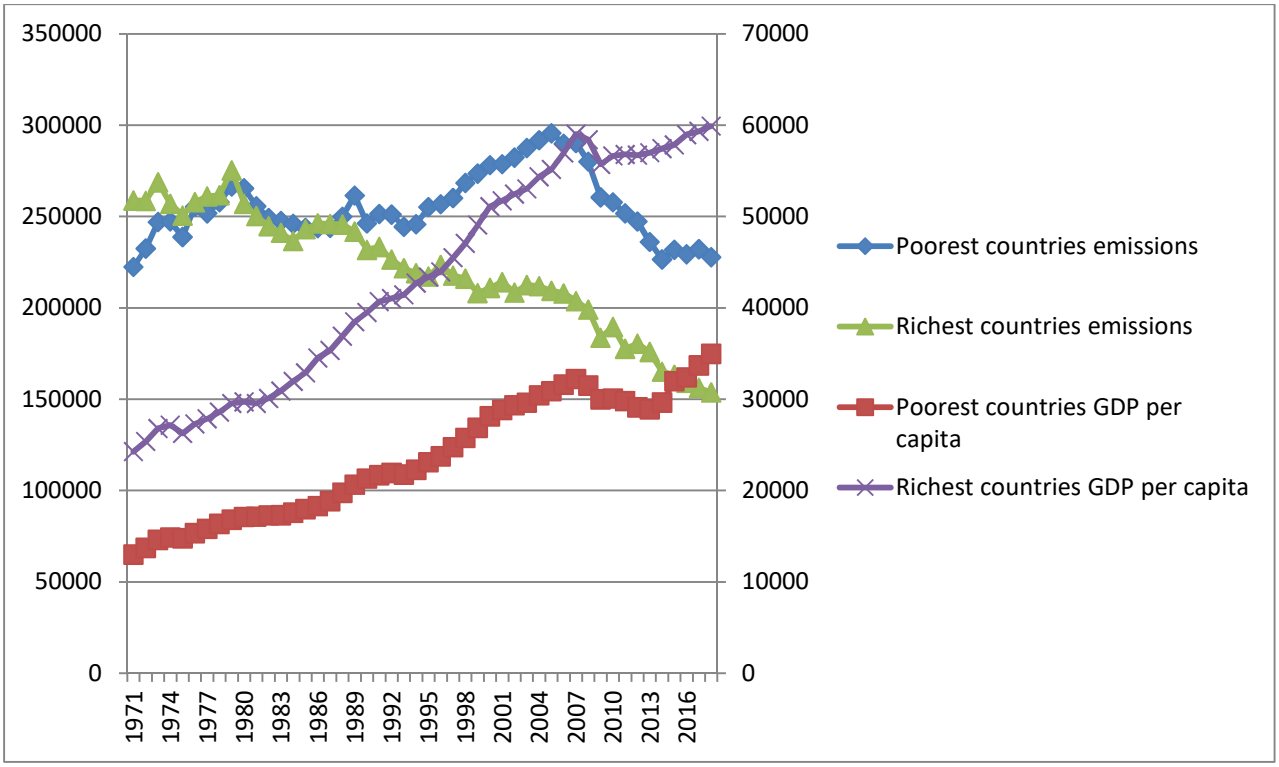
In order to extract some conclusions regarding this topic, we will divide the sample by the GDP per capita median on the year 1971 and analyze the evolution of both the GDP pc and the emissions on each of these groups of countries during the rest of the studying period.

The median of the sample corresponds to the French GDP pc during 1971 which was 18305,18, and the evolution of the data of this groups of countries during the studying period gives us a clear result:

Those countries with a higher income in 1971 have decreased more on average their emissions than those with a worst situation at the beginning of the period. In fact, those countries whose GDP per capita was lower than the median in 1971 have experienced

an up and down in their level of greenhouse gas emissions, a pattern that can be identified with the environmental Kuznets curve.

Figure 21: Evolution of GDP pc and GHG emissions by countries below and above the GDP pc median in 1971 from 1971 to 2018.



Data source: Development Indicators (World Bank database)

As can be observed, both groups of countries have experienced a growth with a similar pace, even higher in the case of those richest countries (which may indicate a structural problem that could be slowing down the growth on those poorest countries). But in the case of the poorest countries, the level of greenhouse emissions shows an inverted U form that fits with the environmental Kuznets curve. In early stages, those poorest countries have experienced an increase on the level of greenhouse emissions, while those yet developed countries not.

We can conclude that this process is not dependent on any country but happens to all of them, but on the case of the richest countries in 191, these countries had already passed

by this process. In fact, looking at the graph, the emission level for the poorest countries is now the same that was for the richest countries when they had the same level of gross domestic product per head.

Maybe, those poorest countries should focus on economic growth since they still are in a stage that will allow them to decrease the greenhouse gas emissions just through the development of their economies. Richest countries also can decrease their emissions while improves their living standards, but since they have stronger and more flexible economies, maybe it would be interesting to adopt some measures that could help to accelerate the decrease on greenhouse emissions.

It is also important to look to the individual evolution of the countries that are part of the sample. All the graphs can be found on the appendix A. At a glance it can be seen that the hypothesis of the environmental Kuznets curve serves to perfectly describe the evolution of emissions in relation to GDP pc in some countries as was explained in the analysis by level of income (that actually coincides in many cases with being part or not of the Mediterranean countries).

4. Econometric analysis

In addition to the descriptive analysis performed in the previous section, we can perform an econometric analysis to deepen our analysis. We will assume a reduced regression like:

$$y_{it} = a + B_1 GDP_{it} + B_2 GDP^2_{it} + B_3 CPI_{it} + B_4 RD_{it} + B_5 COC_{it} + B_6 GI_{it} + e_{it}$$

In equation (1), y is the dependent variable of greenhouse gas emissions, X is the independent variable of income per capita and B is the estimated coefficient for each variable. The first variable is the GDP per head of the country, the second one is the square of the GDP per capita (which measures the effect of the environmental Kuznets curve), the third is the CPI of each country, the fourth is expenditure in research and development, and the fifth is the control of corruption (estimated by world bank data). The e represents the error of the model, a variable that will capture unmeasured factors that can affect our model.

GDP denotes the Gross Domestic Product per capita for each country while it's square test for the existence of an environmental Kuznets curve in our model, the CPI and the control of corruption will test if volatile circumstances in a country political-economic scenario can distort the resource allocation that the system needs to attach the emissions issue.

Finally, another variable is the globalization index, which can affect to the diffusion of technology and thus affect negatively to the level of emissions in the long-run. The idea is to analyze whether inflation (which increases temporal preference on investors, investing in shorter terms) can affect emissions by deincentivizing long-term investments that can help reducing emissions. In the case of control of corruption the procedure is exactly the same, confidence on institutions can affect the risk profile of each investor and also deincentivize long-term investment.

We are going to apply this model for each country to see how the different variables affects for each case.

In the case of Austria, most of the variables are not reliable for the model, and we can reduce the model for just the GDP per head and the investment in research and development, which have a positive and a negative effect in the level of emissions, respectively.

For Belgium, our model is resumed as GDP per capita (with a positive effect on emissions), the square of the GDP (with a negative effect on emissions, giving us the clue that the country is respecting the environmentl Kuznets curve). We also have the control of corruption and the globalization index, both of them affecting negatively to the level of emissions.

In the case of Czech Republic, the representative variables are the GDP, the GDP^2, the CPI, the expenditure in research and development and the globalization index. Both the GDP per capita and the inflation rate seems to have a positive effect on the level of emissions. On the other hand, the country is following the pattern predicted by the environmental Kuznets curve as it has a negative transfer to the emissions, as long as the R&D expenditure and the globalization index have also a negative effect on the emissions.

For France, the variables that affect positively the level of emissions are the GDP per capita and the CPI, while the square of the GDP and the research and development expenditure has a negative transmission to the level of emissions.

In the case of Greece, we can reduce the model to GDP, GDP^2, R&D expenditure and a globalization index. Only the GDP shows a positive correlation with the level of emissions, while the other three variables shows a negative effect on the dependent variable.

In the case of Ireland, the GDP has a positive effect on emissions as well as the inflation rate, while the square of the GDP, the control of corruption and the globalization index have a negative effect on the level of emissions.

In Italy, the model is reduced to the GDP^2, R&D expenditure and globalization index. In this case the square of the GDP have a positive effect on emissions (so the country is not yet under the effects of the environmental Kuznets curve), while the globalization and the research and development expenditure aims to reduce the level of pollution.

Another interesting country is Luxembourg, which shows a positive transfer from the GDP^2 to the level of emissions (rejecting the environmental Kuznets curve). The inflation rate also seems to be harmful when trying to control the level of emissions. On the other hand, the globalization index is having a negative impact on the level of pollution.

For the case of Portugal, the variables are reduced to the GDP (with a positive relationship with emissions), GDP^2 (with a negative coefficient, accepting the environmental Kuznets curve hypothesis), research and development expenditure (with a negative effect on emissions) and the globalization index (which also seems to reduce the pollution levels).

Spain throws unexpecting results, being the only country where the research and development expenditure has a positive transfer to the level of emissions (the more we spend on innovation, the more we pollute). The inflation rate and the GDP per capita also have a positive effect on the level of emissions, while globalization index and the square of the GDP (testing for the presence of the environmental Kuznets curve) shows a negative transfer to the level of pollution.

Finally, in the case of United Kingdom the ,only factor that seems to increase emissions is the GDP per capita, while the R&D expenditure, the control of corruption, the globalization index and the GDP^2 shows a negative effect on emissions.

5. Results and discussion

This study gives us a lot of interesting conclusions that serves to have a better understanding of how greenhouse gas emissions are related to the level of income both in individual countries and in the aggregate euro zone.

We have observed that some countries have performed extraordinary well during the last years; this is for example the case of Czech Republic, Ireland or Luxembourg.

The Czech Republic have decreased its greenhouse gases emissions by a 40% from 1971 to 2018 while its GDP pc has doubled. At the same time, it is one of the countries that has a lower GHG-GDP ratio.

In the case of Ireland, it is the country that have experienced the biggest growth in its economy, it have multiplied its GDP pc by almost 5 in the last years. It is true that Ireland have increased its rate of greenhouse gas emissions, but it is nothing compared with the growth that the country have experienced. In fact, as can be seen in appendix A, not only Ireland is a perfect reflection of the environmental Kuznets curve but it is also one of the countries that have a higher GDP pc than GHG emissions in absolute terms, achievement that was accomplished in the last years.

Another high performer is Luxembourg. Luxembourg is the country with the lowest GHG emissions by unit of GDP pc. Its greenhouse gas emissions has decreased by a 40% while its GDP per capita has doubled in the same period.

UK or France have experienced a bad development, they have decreased their emissions but not increased a lot their GDP pc. In fact, despite the improvement, they are the two economies with a poor eco efficiency. This is shocking since both UK and France have historically been two of the greatest superpowers in the economical and geopolitical European map.

It is the same case for Italy, Spain and Greece. In fact, Greece is the country with a lower increase of their GDP pc while it is one of the countries that have increase more sharply its rate of emissions. Italy and Spain, are the top 3 and 4 countries with a higher GHG-GDP pc ratio. Spain is also the third country with a higher increase of the GHG emissions during the studied period. But on the other hand, it is foreseeable that this countries will improve their eco efficiency during the next years, since they are experiencing the path predicted by the environmental Kuznets curve, where they are now starting the phase in which greenhouse gas emissions reduces when GDP per capita increases.

Portugal is one of the countries with a lower greenhouse gas emissions by GDP pc rate, but on the other hand is the country that have experienced a higher increase in their emissions during the selected period. That is why Portugal is a country with a normal ecological behavior during these years.

Belgium has advanced in the way of becoming a more eco-efficient economy, since it is one of those countries that have effectively reduced its greenhouse gases emissions while it has maintained an acceptable economic growth. Belgium is also one of the countries with a lower gas emissions by GDP pc rate, just slightly higher than Portugal´s one.

Finally, Austria have increased its greenhouse gas emissions during this period but it is still being the third country with a lower rate of emissions by unit of GDP per capita, which makes it one of most eco-efficient economies in the euro-zone.

In addition, one of the main results of this study is the one concerning the environmental Kuznets curve application to European countries. We can observe that the predictions made by this model works extraordinary well in the less developed countries of our sample. So we can extract the conclusion that there is a gap between European economies in terms of eco-efficiency. Those countries which experienced an early development have already passed through the process of increasing environmental damage in order to be able to economically grow. But the rest of the countries, those whose development started lately (as it is the case in most of the Mediterranean countries), are now on the top of that process but seeing how its greenhouse gas emissions are starting to decline.

Finally, besides the fact that 56% of all the greenhouse gas emissions are issued by Mediterranean countries, it is clear that the emissions pace is reducing in both the Mediterranean and non-Mediterranean countries, as well as the ratio between greenhouse gas emissions and gross domestic product per head is also reducing at the same rate for both groups of countries.

Another important result of this study is the one of the correlation coefficient (available in the table 1), which indicates that there exists a negative correlation between economic growth and greenhouse gas emissions. In fact, it is a very good new that increases on the GDP per capita have a transmission of 57% of when talking about reductions in greenhouse gas emissions. This means that GDP can explain almost 32.5% of the total emissions. which leads us to the conclusion that economic growth is not irreconcilable with environmental respect.

So, on the light of this study, it is fair to assert that the future for the European union in terms of eco-efficiency seems to be well oriented, since all the indicators taken into account for the purposes of this study indicates a continuation of the current trend which would allow European countries to keep developing their economies and improving their living standards while they keep reducing their emissions rate in benefit for next generations.

6. Conclusions

The main conclusions arising from this study are that the main trend of the euro-zone in terms of eco-efficiency is positive in the long run, maintaining a sustainable economic growth while decreasing greenhouse gas emissions in most of the countries, or at least not increasing in the same rate that economic growth follows. Also, the rate of greenhouse gas emissions by unit of GDP per capita is decreasing along time in almost every country. It is important to highlight that the extent up to which each economy will see a greater or lower increase in their emissions while their GDP per capita stills growing will significantly relieves on the starting point of that country on this last fifty years.

What can be observed is that the hypothesis of the environmental Kuznets curve serves to explain the evolution of greenhouse gas emissions in respect of the GDP per capita in

most of the countries. Thus, those countries with a lower level of income at the beginning of this period have decreased less or even increased its greenhouse gas emissions, while those countries with a better starting point prior to this period have been able in most of the cases to reduce their emission level while keep increasing their wealth.

This fits perfectly with the environmental Kuznets curve hypothesis that explained how on early stages an increase on the GDP per capita would imply an increase on greenhouse gas emissions, while in latter stages (and after a period of stabilization) the case would be the opposite. In addition to the environmental Kuznets curve, we should add the important metric of the correlation coefficient, which tell us that a 1% increase in GDP per capita is associated with a decline of 0.57% in greenhouse gas emissions for the average euro zone. Of course, this metric varies depending on the country and in all the factors that we have mentioned when explaining the environmental Kuznets curve applied to the sample selected for this study.

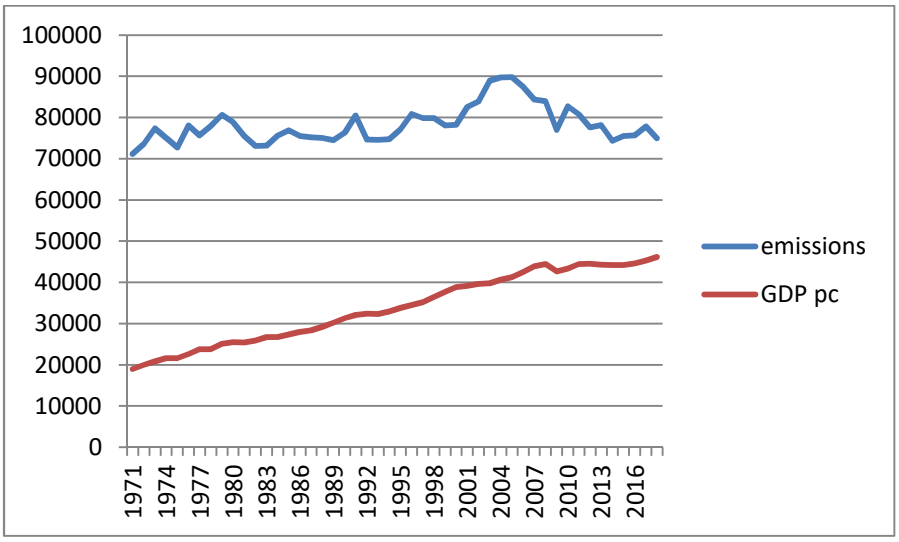
It is also open the possibility that the poorest European countries are experiencing an issue that may be damaging their economic growth, since it can be seen that their economic growth is lower than the one of the most developed countries in Europe. This is actually very strange since it is easier to develop a country when they have to converge upward (copying innovations and attracting external investment). This problem should definitively be attached since as have been seen during this study, most of the European countries will reduce their environmental damage by growing and modernizing their economies in a way that non-polluting sectors gains more relative importance and allows the global economy to absorb the efforts for reducing the current level of greenhouse gas emissions.

By reducing the level of emissions of these countries while keep increasing their GDP per capita at a greater pace, would result on a great leap forward for Europe in order to become a more eco-efficient economy. This would be possible since as have been explained in section 2, 56% of the European greenhouse gas emissions comes from the group formed by the Mediterranean countries. Of course, the effect of those Mediterranean countries would be diluted if we have into account a greater sample of European countries, but it is also true that even when this countries are already the

minority in the selected sample they have the greater impact on the total greenhouse gas emissions.

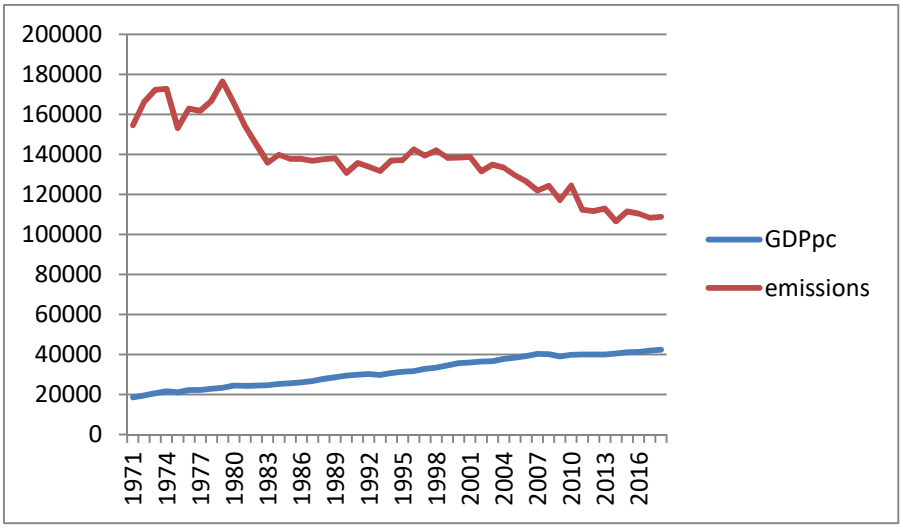
Appendix A

Figure 6: Austria´s evolution of GDP pc and GHG emissions from 1971 to 2018.



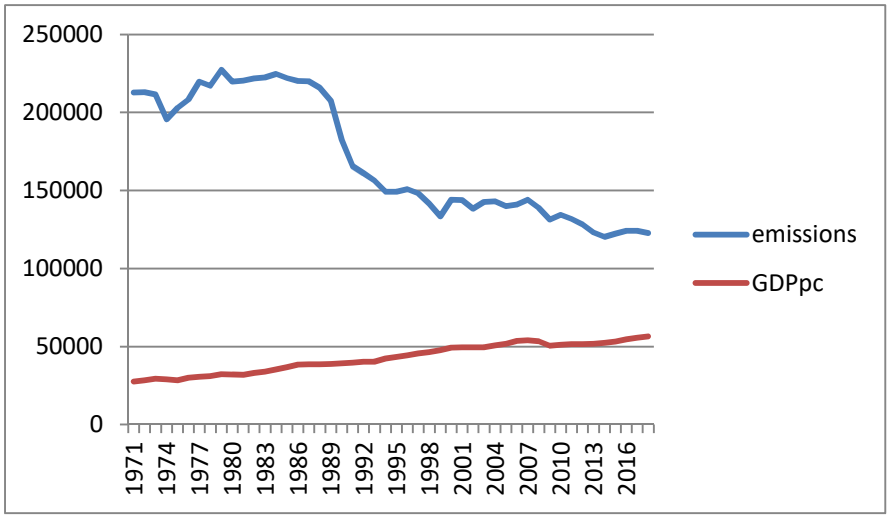
Data source: Development Indicators (World Bank database)

Figure 7: Belgium´s evolution of GDP pc and GHG emissions from 1971 to 2018.



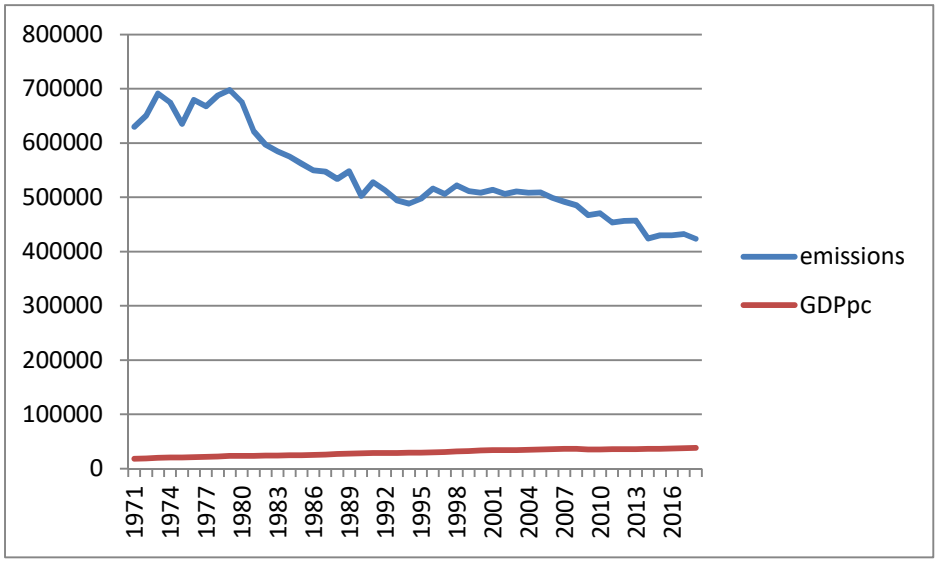
Data source: Development Indicators (World Bank database)

Figure 8: Czech Republic´s evolution of GDP pc and GHG emissions from 1971 to 2018.



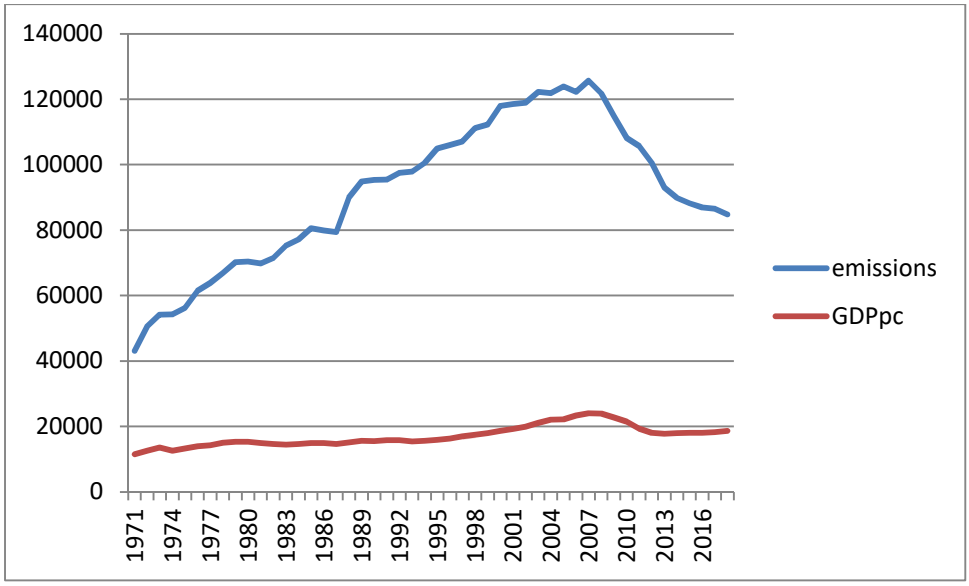
Data source: Development Indicators (World Bank database)

Figure 9: France´s evolution of GDP pc and GHG emissions from 1971 to 2018.



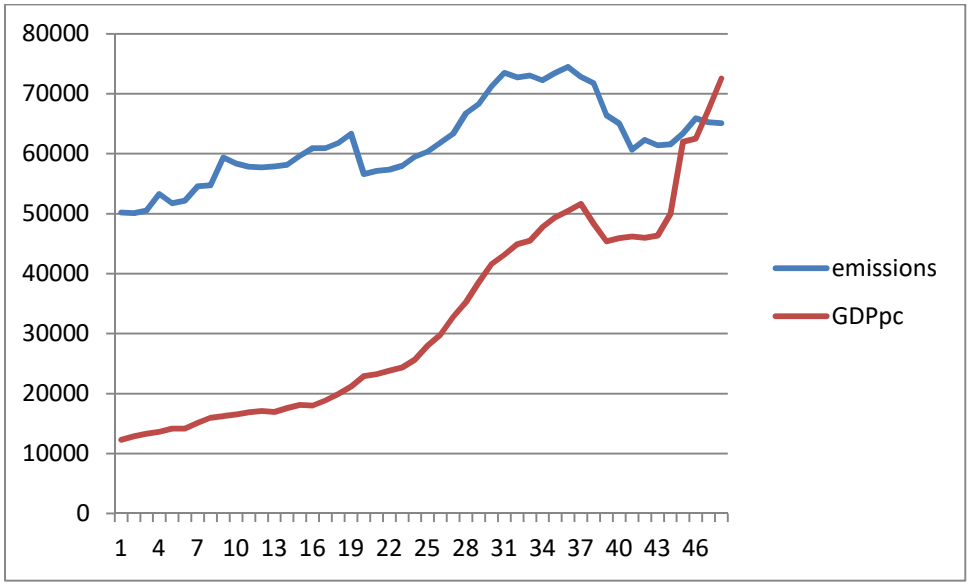
Data source: Development Indicators (World Bank database)

Figure 10: Greece´s evolution of GDP pc and GHG emissions from 1971 to 2018.



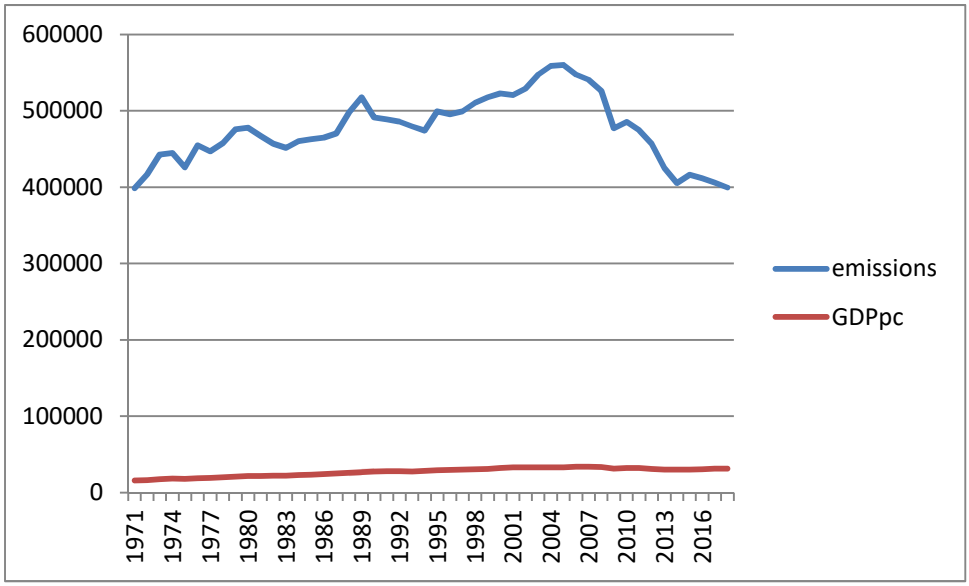
Data source: Development Indicators (World Bank database)

Figure 11: Ireland´s evolution of GDP pc and GHG emissions from 1971 to 2018.



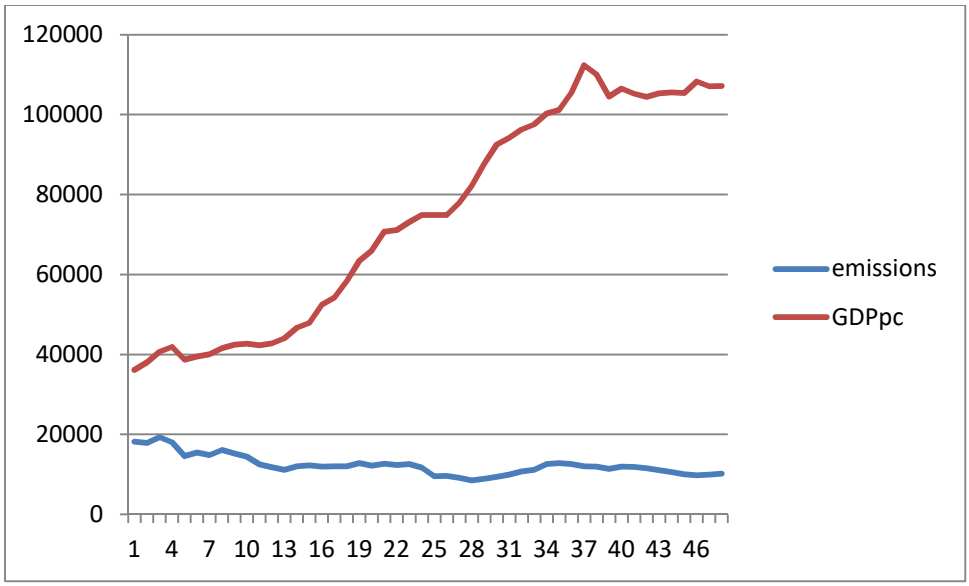
Data source: Development Indicators (World Bank database)

Figure 12: Italy´s evolution of GDP pc and GHG emissions from 1971 to 2018.



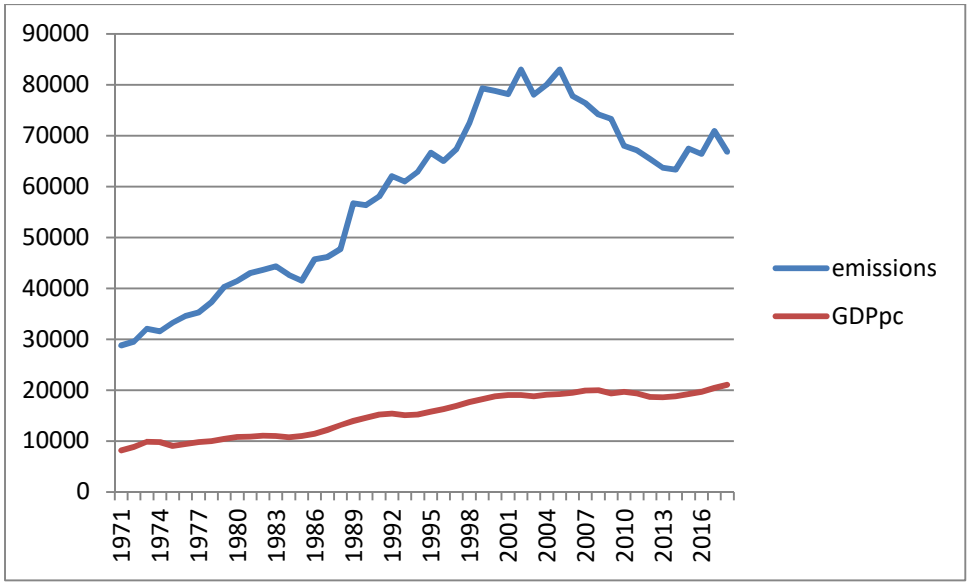
Data source: Development Indicators (World Bank database)

Figure 13: Luxembourg's evolution of GDP pc and GHG emissions from 1971 to 2018.



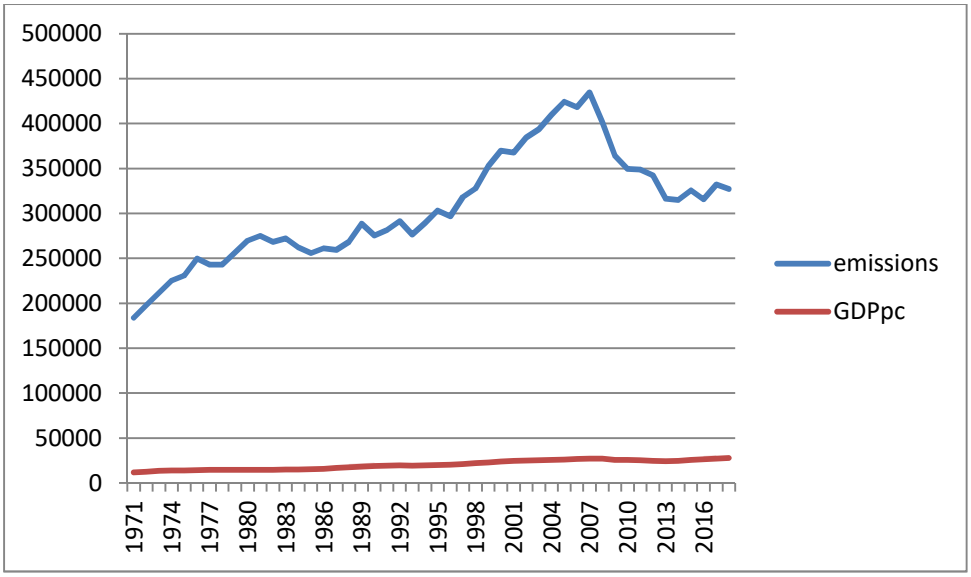
Data source: Development Indicators (World Bank database)

Figure 14: Portugal's evolution of GDP pc and GHG emissions from 1971 to 2018.



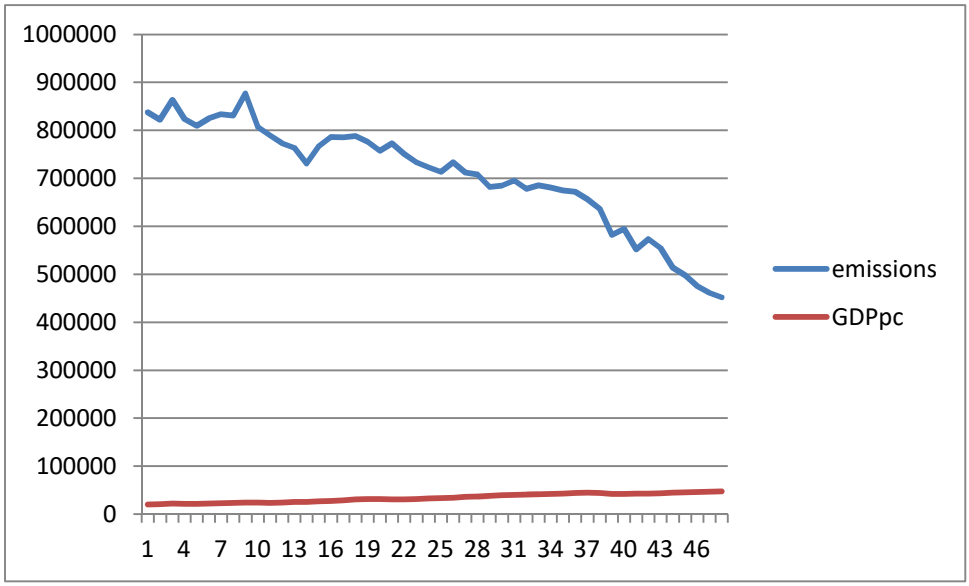
Data source: Development Indicators (World Bank database)

Figure 15: Spain's evolution of GDP pc and GHG emissions from 1971 to 2018.



Data source: Development Indicators (World Bank database)

Figure 16: United Kingdom's evolution of GDP pc and GHG emissions from 1971 to 2018.



Data source: Development Indicators (World Bank database)

Appendix B

Table 1

Coefficient of the selected variables in the regression with dependent variable emissions

Country	*Variable*	*Coefficient*	*Std Dev*	*t-statistic*	*p-value*	*Importance*
Austria	const	33007.3	19938.0	1.656	0.1142	
	GDP	2.14338	0.739447	2.899	0.0092	***
	RD	−16.8441	4.90187	−3.436	0.0028	***
Belgium	const	-265248	142482	-1.862	0.0800	*
	GDP	44.1443	9.34683	4.723	0.0002	***
	GDP2	−0.000506046	0.000109152	−4.636	0.000	***
	COC	−20908.9	11866.0	−1.762	0.0960	*
	GI	−6557.56	1773.46	-3.698	0.0018	***
Czech Republic	const	−769565	248538	−3.096	0.0069	***
	GDP	41.2204	9.45999	4.357	0.0005	***
	GDP2	−0.000386781	9.19655e-05	−4.206	0.0007	***
	CPI	951.241	391.648	2.429	0.0273	**
	RD	−15.7530	3.75312	-4.197	0.0007	***
	GI	−2018.01	953.317	−2.117	0.0503	*
France	const	−708628	483236	−1.466	0.1608	
	GDP	105.742	27.3452	3.867	0.0012	***
	GDP2	−0.00171578	0.000404302	−4.244	0.0005	***

	CPI	7649.70	2358.77	3.243	0.0048	***
	RD	−192.335	26.7775	−7.183	1.53e-06	***
Greece	const	152726	98365.3	1.553	0.1445	
	GDP	30.6348	9.54709	3.209	0.0069	***
	GDP2	−0.000648561	0.000231926	−2.796	0.0151	**
	RD	-8.56593	2.66463	-3.215	0.0068	***
	GI	−4656.02	589.796	−7.894	2.59e-06	***
Ireland	const	196054	28984.4	6.764	4.55e-06	***
	GDP	4.20936	0.659393	6.384	9.06e-06	***
	GDP2	−3.53503e-05	5.90231e-06	−5.989	1.89e-05	***
	CPI	722.137	234.699	3.077	0.0072	***
	COC	−14228.7	4166.52	−3.415	0.0035	***
	GI	−2818.91	488.324	−5.773	2.86e-05	***
Italy	const	318286	145262	2.191	0.0418	**
	GDP2	0.000531315	5.07559e-05	10.47	4.40e-09	***
	RD	−50.9892	13.3676	−3.814	0.0013	***
	GI	−3749.37	1778.57	−2.108	0.0493	**
Luxembourg	const	34600.3	9571.10	3.615	0.0020	***
	GDP2	1.02346e-06	2.31069e-07	4.429	0.0003	***
	CPI	338.520	182.347	1.856	0.0798	*
	GI	−433.864	144.754	−2.997	0.0077	***
Portugal	const	−333266	123395	−2.701	0.0151	**

	GDP	52.0152	14.5095	3.585	0.0023	***
	GDP2	−0.00119094	0.000387958	−3.070	0.0069	***
	RD	−4.61154	1.21866	−3.784	0.0015	***
	GI	-1816.37	377.777	-4.808	0.0002	***
Spain	const	−546289	420834	−1.298	0.2127	
	GDP	238.778	43.1392	5.535	4.52e-05	***
	GDP2	−0.00435220	0.000878311	−4.955	0.0001	***
	CPI	8323.29	2431.08	3.424	0.0035	***
	RD	42.4420	10.9166	3.888	0.0013	***
	GI	−27404.0	3715.78	−7.375	1.57e-06	***
UK	const	543376	696857	0.7798	0.4469	
	GDP	205.530	36.6040	5.615	3.87e-05	***
	GDP2	−0.00252792	0.000421880	−5.992	1.88e-05	***
	RD	−353.954	151.256	−2.340	0.0326	**
	COC	−178990	43413.4	−4.123	0.0008	***
	GI	−36516.3	6904.52	−5.289	7.35e-05	***

Note: Source: Self-elaborated

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