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GRADO EN ECONOMÍA

TRABAJO DE FIN DE GRADO

TÍTULO: The European business cycle and greenhouse gas emissions.

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Abstract:

Our planet is engulfed on a major transformation. Greenhouse gases (GHG emissions) levels are at unprecedented heights, producing devastating effects on our climate and biodiversity. This study analyzes the relation between GHG emissions and the business cycle at the European level. This analysis is done using annual Gross Domestic Product (GDP) per capita as a proxy for the business cycle. With the help of the Hodrick Prescott (HP) filter, the trend from the cycle is deconstructed. The following results appear after analysing the statistics of the variables: first the GHG emissions cycle presents procyclicality with respect to the business cycle in most countries of the European Union. Second, the relative volatility of the emission cycle is greater than the volatility of GDP per capita in most economies. And finally, there is a decreasing correlation between procyclicality of emissions and GDP per capita.

1. Introduction

The rise in temperature is one of the most pressing issues in society, such is the case that it could threaten our water supply (Wiltshire et al, 2013). Given that it is a key component in accelerating climate change, it has the potential to completely change our way of life by destroying the environment. It is therefore of vital importance the comprehension of how GHG behave when our economies move along the cycle, so policy makers can be better prepared to enact policies in key sectors as energy consumption (Yang and Timmermans, 2020).

One of the key figures to predict the impact of emissions in present times is the social cost of carbon. It is usually defined as the potential economic damage. New studies have found that the new predictions for this damage are set to be on the interval of 117-805 dollars per ton of C02 emitted (Ricke et al. 2018). These figures enhance the importance of studying the relation of economic growth and emissions.

This study analyses the GHG emissions correlation with the business cycle in the European environment. by utilizing data from 28 European countries[1], the information obtained is more consistent with the regulatory environment. Taking into consideration the notion of conditional convergence and studies made in this field (Awaworyi Churchill et al, 2018) it supports the premise that taking a smaller sample more constrained can show more meaningful results

Previous studies have proved to be a positive and procyclical relation between C02 emissions and the business cycle in a global sample (Doda, 2014). Yet the global sample, diminishes a more concentrated analysis. There are also studies in the US that have proven that optimal policy helps dampen the procyclicality of

[1] The EU 28 as defined by the European Commission comprise: Austria, Italy, Belgium, Latvia, Bulgaria, Lithuania, Croatia, Luxembourg, Cyprus, Malta, Czechia, Netherlands, Denmark, Poland, Estonia, Portugal, Finland, Romania, France, Slovakia, Germany, Slovenia, Greece, Spain, Hungary, Sweden, Ireland and United Kingdom. Although United Kingdom has left the EU in 2020, since our sample ends in 2015 it will be included in the sample.

emissions (Heutel, 2011). Thereby, it will be of key interest to see if it is the case of the European Union (EU), where there has been an emission trading system (ETS) policy since 2005. The EU membership has proved to be one of the most crucial factors explaining a strong domestic environmental policy for its members (Liefferink et al, 2009) as explained by the authors, most likely for the policy transfers from leading countries such as Sweden.

The three main objectives of the study is to proof that: the EU emissions cycle presents procyclicality with respect to the business cycle, emissions are relatively more volatile than GDP and finally that there is a decreasing correlation between the cycles and the increase in GDP per capita.

The division of this study will be as follows. Firstly, introducing the data and its particularities. Then into full extent the methodology will be presented, with specific considerations and explanations of the filtering method. The results of this method are going to be presented in a section. To broad the knowledge on the subject, a discussion section debates possible implications on policy from the findings. Finally, a conclusion is set to be drawn to summarize the key takings and implications of the results obtained

2. Data

For the analysis of this paper there are two variables of crucial importance: the GHG, which comprise fossil CO2, CH4, N2O and the F-gases. This variable is going to be used as a proxy for emissions. The second variable is GPD per capita, which will be used as a representation of the business cycle. Both variables are represented as a time series and have an annual frequency, which has the advantage of eliminating seasonal components

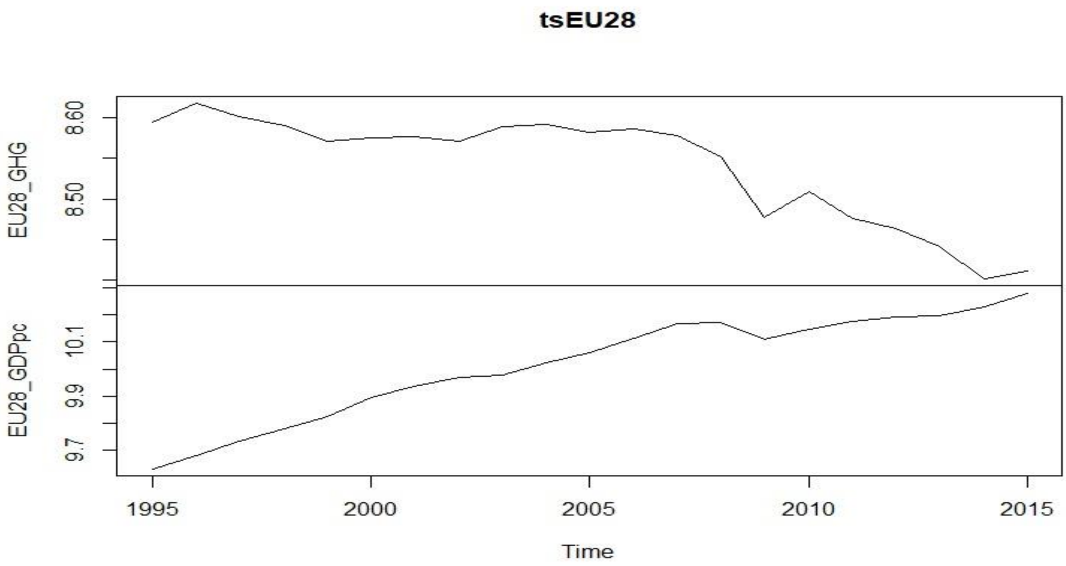
The GHG data is provided by the Emissions Data Base for the Global Atmospheric Research EDGAR (2020) of the European commission. There are other sources for GHG data, such as the Climate Analysis Indicators Tool (CAIT) of the World Resources Institute (2020). A key significance of the database provided by EDGAR is the time length, it has data from 1970 which adds robustness to the findings. On this study, GHG data is extracted from EDGAR database.

The GDP per capita is provided by Eurostat (2020) and The Conference Board Total Economy Database (2019) (TCBED). The first database offers statistics of the EU28 countries however it the data is only registered from 1995, because of that, individual countries are extracted from the second one which compile data from 1950 to 2019. Although the currency is not the same in the two data bases, this should not affect the analysis, as the key interest is the cyclical component and not the magnitude.

To treat this data, we take the natural logarithms. After that we use the HP filter, using R studio version 3.2.6 as the analytical tool. The function is given by the package mFilter (Balcilar 2020). Applying the code to the series aims to separate the cyclical component of the series from the trend. The use of filters does not come without criticism which will be discussed in detail.

On the following figure created with R studio, we see the evolution of the GHG emissions and GDP per capita for EU28 in natural logarithms. from eye inspection a negative slope can be observed, indicating a reduction in the emissions over time for the EU. Opposite to GHG the GDP per capita has been increasing during the last 20 years.

Figure 1 Logarithmic scale of data for EU 28



Source: authors work. Legend: EU28_GHG: natural logarithm of GHG, EU28_GDPpc: natural logarithm of GDPpc.

3. Methodology

In order to obtain the cyclical component of a time series, it is important to apply a filter. The decision to apply such a filter is a controversial one, the argument has been made that filters detrending time series provide different results Canova (1998). Yet as Burnside (1998) responded it is only normal that different filters will yield different results given that they also have different interpretations. However, HP filter has remained as one of the most relevant filters for economic time series. One strong argument in favour is that, because time series data includes short term shocks and other disturbances that must be addressed the need of a filter becomes evident.

To separate the cycle component from the growth or trend component, the Hodrick Prescott filter is applied. This filter allows to obtain a smoothed non-linear representation that can capture its long-term behaviour such as a business cycle.

The HP filter decomposes a time series $\boldsymbol{y_t}$ into a growth and cyclical component ($\boldsymbol{g_t}, \boldsymbol{c_t}$) e.g $\boldsymbol{y_t = g_t + c_t}$. The HP filter extracts the trend component $\boldsymbol{g_t}$ form a series $\boldsymbol{y_t}$ by following this minimization problem, as shown below:

$$\boldsymbol{min_{\{g_t\}} = \left[\sum_{t=1}^{T} C_t^2 + \lambda \sum_{t=1}^{T} [(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2\right]}$$

$$\boldsymbol{Subject\ to\ \ y_t = g_t + c_t}$$

$$\boldsymbol{y_t, \lambda\ given}$$

Here, $\boldsymbol{\lambda}$ is a multiplier or a penalty parameter that is used for the adjustment of the sensitivity of the trend to short-term fluctuations best described by Hodrick and Prescott (1997). The first term of the minimization problem puts a penalty on the variance of the stationary component $\boldsymbol{c_t}$ and as such it is a measure of the time series fit. The second term is a measure of smoothness as it penalizes the lack of smoothness in the trend component $\boldsymbol{g_t}$. There is a conflict between goodness of fit and smoothness. To keep track of this problem there is a “trade-off” parameter $\boldsymbol{\lambda}$.

When $\boldsymbol{\lambda}$ is zero, no noise is assumed and the trend component become equivalent to the original series (i.e $\boldsymbol{y_t}$= $\boldsymbol{g_t}$), while as $\boldsymbol{\lambda}$ diverges to infinity the trend component approaches a linear trend. Hodrick and Prescott (1997) show that under some conditions the best choice of parameter $\boldsymbol{\lambda}$ that minimizes the sum of errors is driven by the relative variances of $\boldsymbol{c_t}$ and the second difference of $\boldsymbol{g_t}$. Thus, the HP filter removes a trend from the data by solving a least squares problem._Hodrick and Prescott (1997) suggests using a value of $\boldsymbol{\lambda}$ =1600 for quarterly data, however its value has been at the core of the discussion when considering other data frequencies. For annual data, its value has varied from 100 Backus and Kehoe (1992) to 10 by Baxter and King (1999) however a study performed with US GDP found that choosing the value 6.25 for annual data yielded the same trend as using 1600 for quarterly data Ravn and Uhlig (2002) given this evidence, on this study, $\boldsymbol{\lambda}$ will be equal to 6.25.

The HP filter is a widely used tool in empirical macroeconomics where it has been used in the study of business cycles. Its use is not limited only to this area, though. Weron and Zator (2014) Used the HP filter in electricity markets to facilitate the cyclical component of prices, without the numerical complexity of a wavelet-based model traditionally used in these studies.

However, there is a strong empirical evidence that suggest filtering data with the Hodrick Prescott filter generates random correlations at business cycle frequencies, with random data (Cogley and Nason 1995). Because there is such a challenge and as proposed by the paper, the natural logarithms of the data have been previously cross correlated. The results show the data is strongly correlated and with statistical significance. So, it is safe to assume there are no random correlations being induced by the filter

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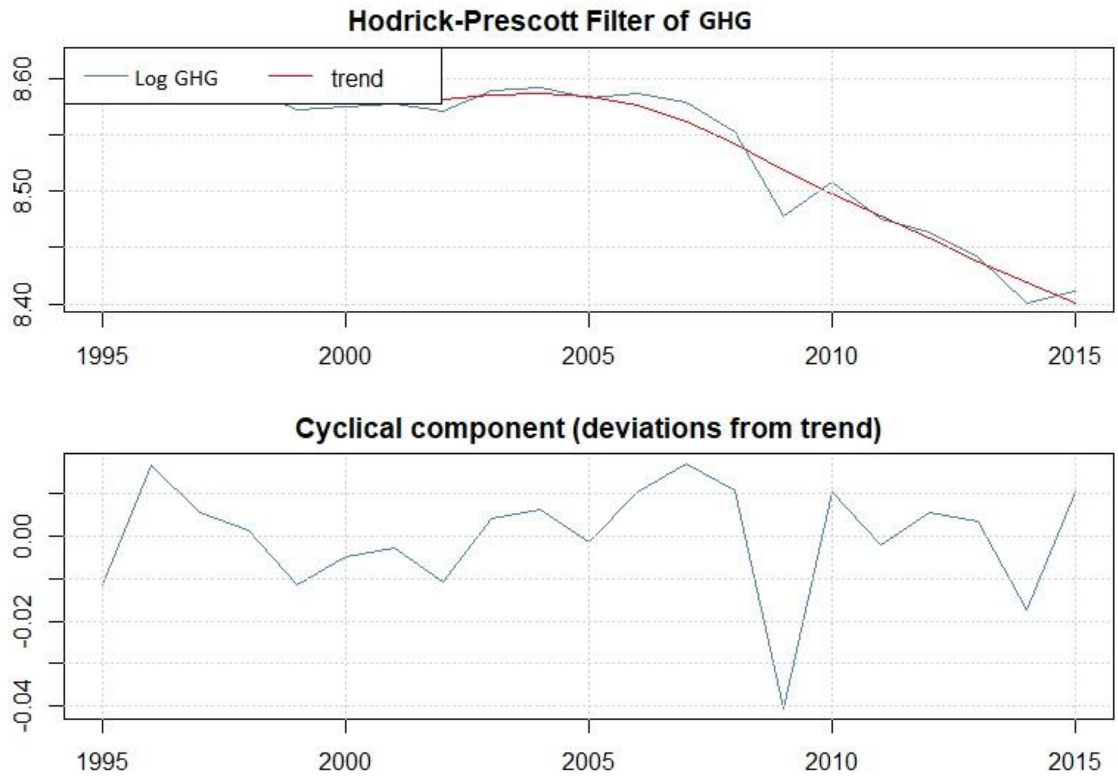
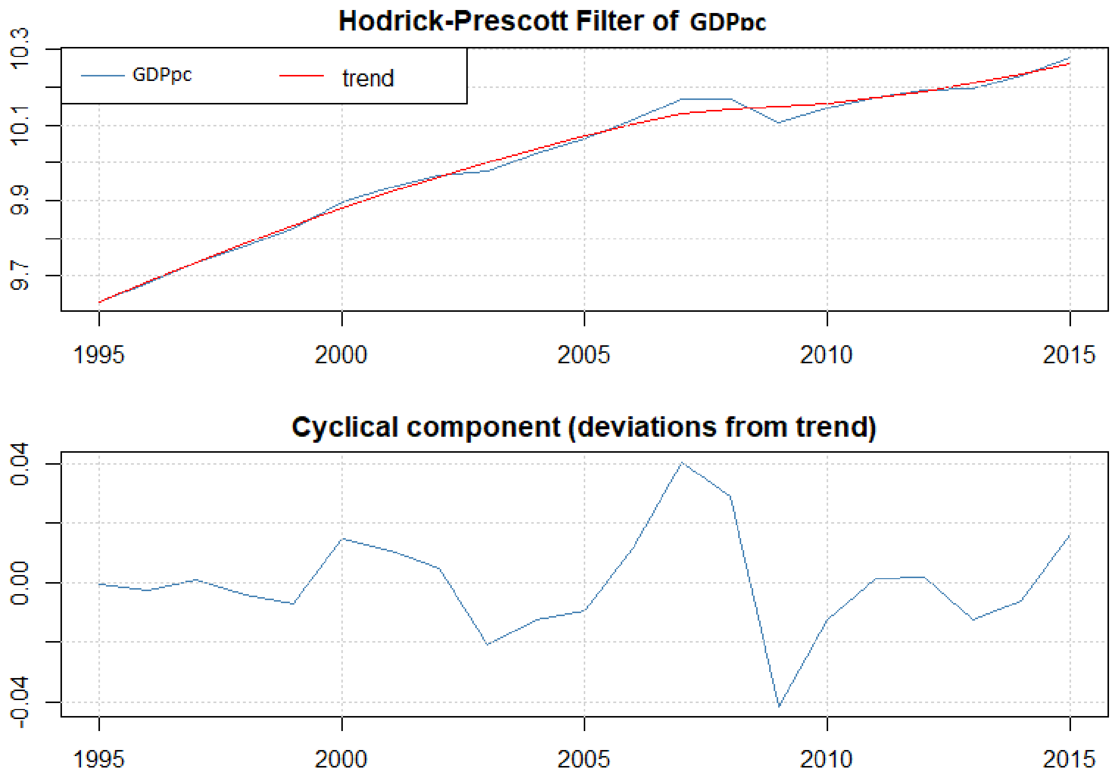
From figures 2 and 3 we appreciate how the HP filter, de-trends the data and extracts the cycle. For the EU28 data, as an economic zone, using R studio to run the code.

Figure 2



Source: authors work

Figure 3



Source: authors work

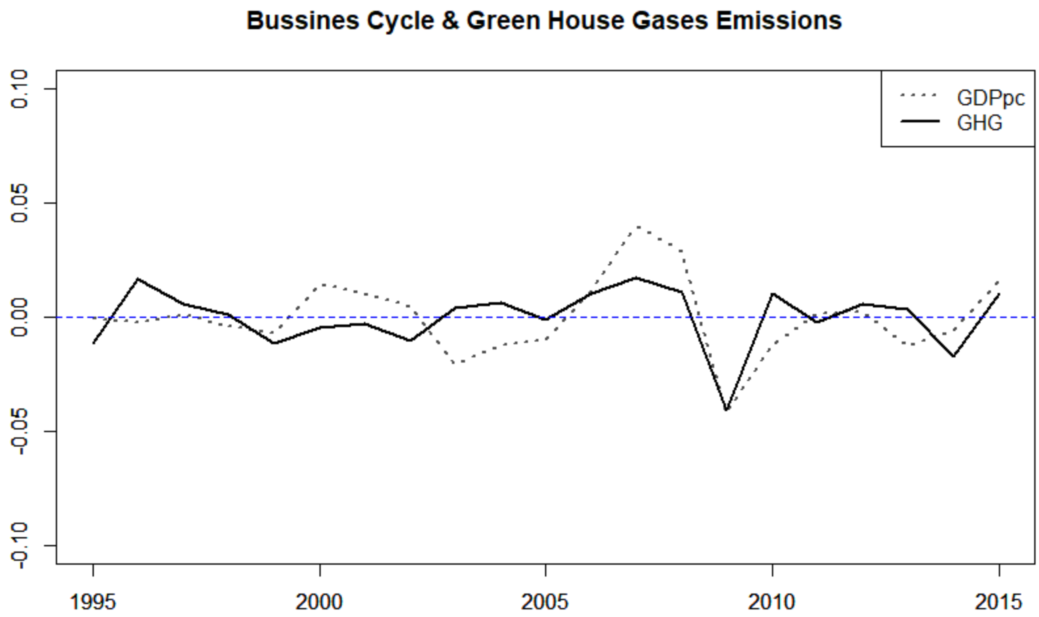
The results immediately show that there is a historic relevance to the data. Observing both figures, the crisis of the early 2000 is clearly visible, also the Great Depression of 2008 is fully observed including its recovery.

Finally, taking both the GHG and GDP per capita cycle for the period, the cross-correlation function (CCF) is obtained from the time series obtained. The CCF indicates if the variables are correlated and if such at which period. A positive correlation in period 0, would indicate procyclicality. The standard deviations of the cycles will indicate their respective volatilities.

4. Results

From Figure 3, visual inspection induces the intuition of a co-movement or commonly known as procyclicality of the two cycles in the European Union. This intuition is confirmed by the results observed in table 1 from the annex(T1). The CCF of the data shows this is a consistent relation in most of Europe's countries. The data, however, does not indicate whether there is a lead or lag variable as no statistically significant results were observed in the lagged periods of the cross correlation.

Figure 3

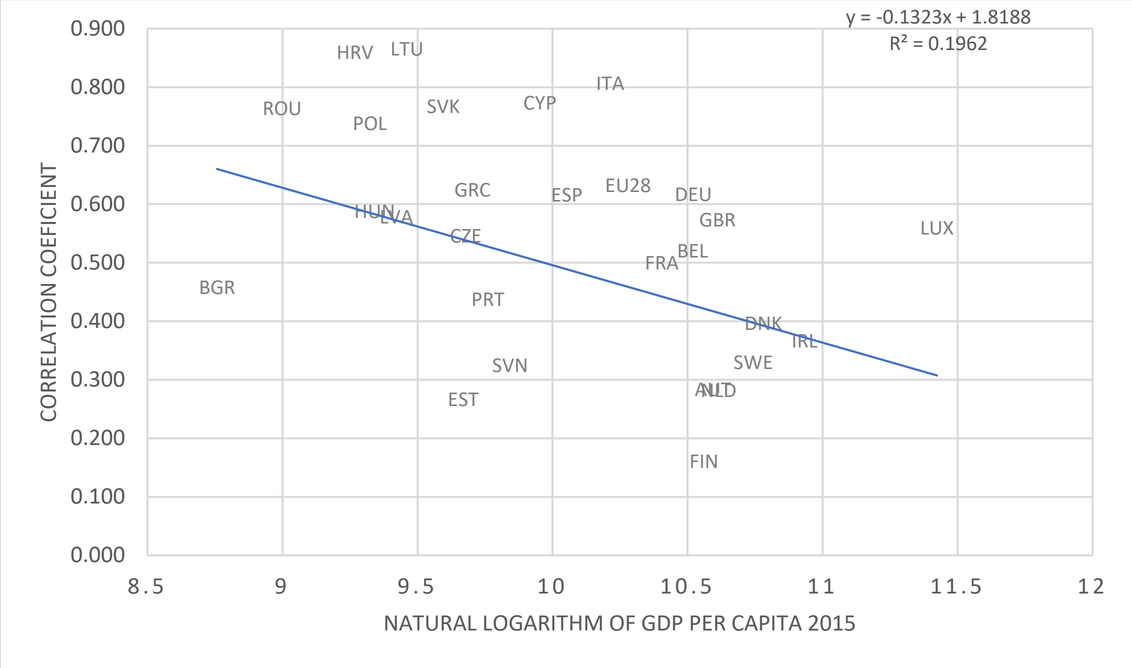


Source: authors work.

Another important result is that in general there is a greater standard deviation of the GHG cycle compared to the GDP per capita. And thus, the relative volatility of GHG emissions with respect to GDP is greater than 1 in most cases.

The findings regarding volatility and procyclicality of the cycles matches those proved by Doda (2014) with a sample of 122 countries. Indicating that the European Union generally follows the global trend on this issue.

Figure 4



Source: authors work.

Figure 4 presents the following interpretation, as GDP per capita increases the correlation coefficient decreases. However, this relation does not have a strong statistical significance having a p-value only significant at a 5%. This regression has also been made for GDP per capita in 2009 showing the same sign in the coefficient and significance level.

With regards to clusters of data with similar characteristics, the big five economies of Europe (ITA, GBR, DEU, FRA and ESP), all are above the linear line, and relatively close together. However, there is no clear distinction in the geographical distribution of the economies or their productive structures in the plot, a more industrialized economy as Germany does result in a higher coefficient nor is near other industrialized economies as the Netherlands.

This however is not void of logic as recent studies on the analysis of emissions by sector have proven, services sector has been historically underrated as a polluter Gadray (2011). These findings are derived from the fact that services are heavily linked to material goods. Taking into consideration this study, makes sense that Greece, a services economy, shows a similar coefficient as Germany.

Taking into consideration EU28 as a reference point for countries in the European Union. Spain lags in the GDP per capita but is average in the CCF coefficient. Following the trend in most of the macroeconomic indicators of the Spanish economy.

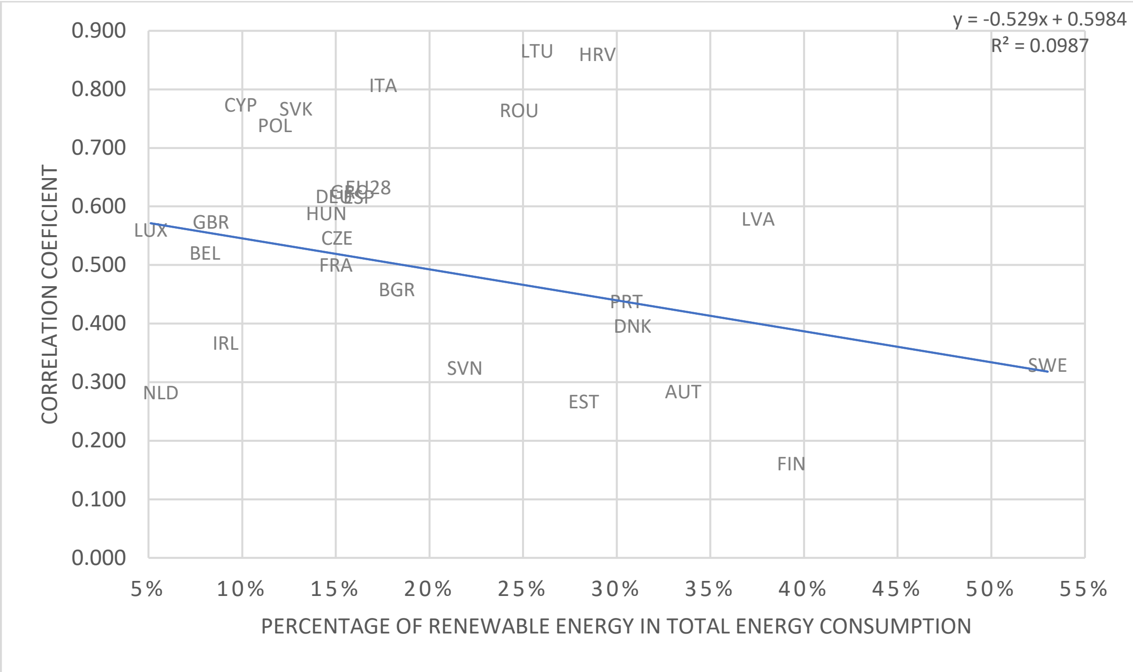
5 Discussion

The results obtained from the linear model of GDP per capita and the correlation coefficients, point a shifting position of the European Union, with respect to Baron Doda findings. This being the negative relation of the economic development with the correlation. However, there are key differences on the data. The sample size of his work has 122 observations from some countries. The smaller data might produce lower coefficients, caused by the decarbonization of the energy sector from the last decades in the EU, as well as the integration of the energy markets. There is also an increase in the percentage renewable energies and natural gas in the European energy in last 20 years, which would again delude the relation between the economic cycle and emissions.

The negative slope of the linear model in figure 4 corroborates the findings of Heutel (2012) where optimal policy carbon policy dampens the procyclicality of emissions when comparing unregulated states. As we see countries that are considered leaders of environmental policies have the smallest coefficients (Sweden amongs others). This relation is further analysed by Fishcer and Spingborn (2011) who proof the best policy to be a “cap” on emissions rather than a tax, because it dampens procyclicality of emissions and does so with less volatility. Since 2005 Europe has implemented an emission trading system, a cap trading system, far more ambitious than any other country (Hood, 2010). The last report from the European Commission indicates that the block is on track for a 21% reduction of emissions by 2020 since its implementation.

As Baron Doda speculates. investment in renewable energy resources and a greener grid could reduce the procyclicality of emissions. Taking data from Eurostat for renewable energy consumption as a percentage of total consumption, a comparison can be made with respect to the coefficients. In figure 5 we can see this relation, yet the model is not statistically significant.

Figure 5



Source: authors work. Data from EUROSTAT

The statistical insignificance of figure 5 is not a surprise, considering the findings of Winter (2014). As he describes, an optimal carbon policy should outweigh the effects of a greener energy production.

Further research

Interesting lines of investigation on this subject could be to include a detailed analysis of the effect of the amplitude of the cycle on the emissions and the correlation with the business cycle.

On the other hand, performing this analysis with quarterly data could allow for a more granular analysis of the relation between these cycles. A deeper analysis into the effects that seasonality has in the cycles of countries with a big tourist sector, could give better understanding on the service sector and emissions.

6 Conclusion

Through the homo sapiens history, it has never been recorded higher levels of GHG on our atmosphere (Meinshausen et al. 2017). These changes, have only increased since the industrial revolution, producing adverse effects on our planet. Nowadays it is not science fiction to think, that one day, this blue dot in the solar system could be unhabitable for humanity.

The current price of not enough action, on this pressing subject, might be too high to afford a passive attitude. Because of this, the importance of research in this field of economics has never been more important.

On this study, the data used to perform a macroeconomic analysis of the business cycle was provided by three sources: Eurostat, EDGAR and TCBED, constraining the field of study to the countries of the EU. The methodology used, although not lack of controversy, has endured the tests placed and proved to be a useful analysis tool. Producing three key results. First GHG emission cycles of the European union are generally procyclical with respect to the cycle of GDP per capita. Secondly the relative volatility of emissions is bigger than 1 in most EU countries. Finally, there is a negative relation between GDP per capita and the coefficient of the CCF.

This last result could pose an empirical base for the environmental Kuznets curve hypothesis. This hypothesizes that; the first stages of economic development, the environmental impact is higher, but as GDP per capita increases the impact diminishes (Kuznets, 1955). Assuming that smaller procyclicality of our emissions is equivalent to a lower carbon intensity economy.

The general data for the European Union has a positive ending. It is true that thinking in a global scale there is much opportunities to work and achieve. But is also true that the European Union is working on this important issue and that could be interesting to see how could serve as an example for developed and developing economies around the world.

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Annex 1

Table 1 Cross correlation coefficients

ISO	COUNTRY	CCF		σ:GHG	$\sigma: GDPpc$	Relative volatility	Sample
AUT	Austria	0.230		0.022	0.010	2.120	N=46
BGR	Bulgaria	0.405	***	0.034	0.029	1.150	N=46
BEL	Belgium	0.467	***	0.025	0.010	2.448	N=46
HRV	Croatia	0.806	***	0.038	0.037	1.011	N=36
CYP	Cyprus	0.720	***	0.041	0.044	0.931	N=46
CZE	Czechia	0.493	***	0.020	0.020	1.006	N=46
DNK	Denmark	0.343	**	0.041	0.013	3.083	N=36
EST	Estonia	0.213		0.104	0.043	2.433	N=46
FIN	Finland	0.108		0.037	0.020	1.843	N=46
FRA	France	0.447	***	0.018	0.009	1.923	N=46
DEU	Germany	0.563	***	0.0175	0.013	1.326	N=46
GRC	Greece	0.572	***	0.017	0.020	0.850	N=46
HUN	Hungary	0.535	***	0.027	0.020	1.373	N=46
IRL	Ireland	0.313	**	0.018	0.019	0.953	N=46
ITA	Italy	0.753	***	0.018	0.012	1.438	N=46
LVA	Latvia	0.526	***	0.029	0.058	0.505	N=36
LTU	Lithuania	0.812	***	0.059	0.048	1.235	N=36
LUX	Luxembourg	0.507	***	0.043	0.021	2.084	N=46
MLT	Malta	-0.134		0.070	0.019	3.769	N=46
NLD	Netherlands	0.229		0.019	0.011	1.714	N=46
POL	Poland	0.685	***	0.024	0.021	1.152	N=46
PRT	Portugal	0.385	***	0.024	0.021	1.162	N=46
ROU	Romania	0.711	***	0.038	0.032	1.181	N=46
SVK	Slovakia	0.714	***	0.026	0.034	0.773	N=31
SVN	Slovenia	0.271		0.034	0.024	1.402	N=36
ESP	Spain	0.563	***	0.024	0.012	1.968	N=46
SWE	Sweden	0.276	*	0.025	0.014	1.836	N=46
GBR	United Kingdom	0.520	***	0.019	0.013	1.421	N=46
EU28	EU28	0.579	***	0.013	0.017	0.764	N=20

*Source: Authors work. Note: the coefficients marked mean they have been tested with the null hypothesis that the coefficient is equal to 0. *=p<0.1, **=p<0.05, ***=p<0.01Legend:. σ:GHG: standard deviation of GHG cycle, CCF: Cross correlation coeficient, $\sigma: GDPpc$ standard deviation of GDP cycle, Relative volatility = σ:GHG/$\sigma: GDPpc$*