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The Influence of Imports and Exports on the Evolution of Greenhouse Gas Emissions: The Case for the European Union

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Abstract: Part of a country's emissions are caused by producing goods for export to other countries, while a country's own needs also generate emissions in other parts of the world that are associated with the products they import. Our interest was to evaluate the influence of imports and exports of goods and services on greenhouse gas (GHG) emissions in a data panel composed of 30 countries over 21 years. We included as control variables the gross domestic product per capita, employment, an indicator of the economic crisis and a non-linear trend and inferences were performed using a Bayesian framework. The results showed that it was the exports and imports of goods, rather than services, that were related to CO_2-equivalent levels. Exports and imports of goods were very inelastic, albeit less so in the case of the index. In summary, the more a country imports, the higher their GHG emission levels are. However, it is important to point out that when employment rates are higher more energy is consumed and GHG emissions are greater. In richer countries, GDP per capita is the factor that best explains why their emissions are so high.

Keywords: greenhouse gas emissions; consumption; exports; imports; employment; GDP

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1. Introduction

For many years the world has been immersed in a spiral of economic growth based on an unsustainable development model, reflected in the lingering economic crisis suffered since 2007 and climate change. We must bear in mind that carbon dioxide (CO_2) emissions continue to be linked to economic development, although the economic crisis and the recession has slowed this trend down slightly in recent years. The European Union (EU) has committed to reducing its greenhouse emissions by 20% below 1990 levels by 2020. According to the reports 'Approximated EU greenhouse gas inventory: early estimates for 2011' [1] and 'Greenhouse gas emission trends and projections in Europe 2012' [2], EU GHG emissions decreased by an average of 2.5% between 2010 and 2011, even though they increased in some other countries.

In some countries, the economic crisis together with strong pressure to reduce contaminating emissions has brought about industrial delocalisation to emerging countries. These industries are often those that contaminate most and so these moves have not meant a global reduction in emissions. Delocalisation has caused these emerging countries' exports to rise to the levels of other countries. To give an example, China's exports have grown by 20% annually since 2001 and their factories, together with those of other emerging economies currently cause more carbon contamination than the sum total of America and Europe's industries. This contamination, however, is caused by manufacturing goods for export. If we take a look at the evolution of the emissions generated in other countries with average incomes but less exports, we can see that this increase has been much more gradual and emissions in the world's poorest countries have remained at very low levels since 1990. While it is true that the elites in countries like China, India and Brazil are consuming more and more goods and services, their emissions per capita are still lower than either America's or Europe's. This theory is used by many countries to argue that the increase in their emissions is due to the growth in the production required to cover their exports and seen from this perspective they are not at fault, but rather the countries that import their products.

Part of the emissions generated in a country are certainly caused by producing goods for export to other countries, but on the other hand, a country's own needs generate emissions in other parts of the world that are associated with the products they import. Thus, seen from this point of view, a country is responsible for all the direct and indirect emissions associated with the production of goods required internally.

According to Dietzenbacher [3], in reality this is not the case because when these emerging countries are exporting what they do to be able to carry out this process is foster an increase in intermediate product and raw material imports. In other words, emerging economies are exporting products whose pieces have been produced previously elsewhere in the world, so the emissions derived from this last production link are small. If we only consider our own national inventory to understand trends in emissions we are not seeing the full picture of our impacts. Thus, we have to understand the entire life cycle of all the goods and services we are buying and selling.

According to Degain and Maurer [4], in China for example the average imported content of Chinese exports in 2008 was 37%, reaching 56% in the case of products coming from processing zones for export. Thus, it cannot be said that there is a relationship between increased emissions and growth in exports. According to Dietzenbacher [3]) 'the growing increase in Chinese emissions within the international context cannot be attributed to the growth in their exports, but to the fact that this country needs in the order of 4.4 times more electricity than Germany and 6 times as much as Japan to generate their gross domestic product (GDP), and in the order of almost 3 times the average of the rest of the world. What is more, this electricity is generated almost entirely from carbon, the energy source that emits more CO_2 per unit of energy generated that any other'.

In 2012, the average rate of unemployment in the EU was almost 11%. If we focus on the difference in the unemployment rates of northern and southern European countries, in 2000 it was 3.5 points, going down to zero in 2007, then increased rapidly to 7.5 points in 2011. Outside the Eurozone divergence also increased but much less significantly so [5]. This situation has meant that family incomes have decreased as the real available gross income went down between 2009 and 2011 in two thirds of EU countries, most notably in Greece (17%), Spain (8%), Cyprus (7%), Estonia (5%) and Ireland (5%). This evolution contrasts with the situation in countries such as Germany, Poland and France where social protection systems and more resistant labour markets have allowed overall incomes to carry on increasing throughout the recession. The continuing crisis, however, increases the risk of long-term exclusion and poverty in all countries.

Between 1990 and 2010 consumption in the EU increased by 33%. We must be aware that this dynamic and the need to consume resources, which for many years were a source of income and employment and, most importantly, suffused societies with a greater sense of wellbeing, are just one side of the coin because this behaviour has also created serious environmental problems. To give an example, generating the electricity needed to recharge our mobile phone and refrigerate our food releases carbon dioxide into the atmosphere, which contributes to climate change. Industrial installations and transport release atmospheric contaminants like sulphur dioxide and nitrogen, which are harmful to human health, but it is in fact the main GHG produced by human activity—CO_2—that makes up 82% of all GHG emissions in the 27 EU member states.

Literature Review

When reviewing the literature related to the influence of imports and exports on the evolution of GHG emissions, it was observed that none of the articles focused exclusively on analysing either how imports and exports influence the evolution of GHG emissions or if there is a cause effect between employment and these emissions.

However, articles related to trade were found. For example, an article that relates the growth of CO_2 emissions in a Chinese city to GDP growth per capita and considers that this is driven by several factors, one of which is exports, can be highlighted [6]. Another article relates economic growth with increased emissions, but focuses mainly on international trade related only to maritime transport [7]. Further articles include one that takes Beijing as a case study and focuses on measuring the CO_2 emissions incorporated in interregional trade [8], another [9] that relates air quality to economic growth, considering the impact of trade barriers on analysing imports, and a third that analyses CO_2 emissions and GDP, considering the impact of trade liberalization for countries in the Middle East and North Africa [10]. Finally, a study was identified that links carbon emissions, energy consumption, income and foreign trade for the case of Turkey [11].

The literature review also uncovered different works that analyse the links between economic growth, energy consumption, environmental quality and CO_2 emissions, many of which use the Environmental Kuznets Curve (EKC), or what is known as the Carbon Kuznets Curve Hypothesis (CKC). Kuznets's pioneering work [12] claimed that there was an inverted U-shaped relationship between economic growth and income inequality, which was then reformulated to prove that there was a similar inverted U-ratio between economic growth/income and environmental quality. The literature shows that several authors use this hypothesis to analyse the relationships between environmental quality, energy consumption and economic growth. Deepening the analysis of the articles, we find that in terms of environmental quality water, sanitation, waste and emissions have been considered [13], and under Kuznets's hypothesis the influence of other variables that affect CO_2 emissions have also been measured, such as technological and demographic changes [14] and imports and the tertiary sector in the case of Austria [15], among others [16,17]. Other works analyse the relationship between carbon emissions, energy consumption and economic growth, associating this with the EKC. These include the case of France [18], an article that considers 19 European countries [19], a case for the BRICS countries but without Russia [20], the case of China [21], an analysis in 11 independent states [22] and the cases of Taiwan [23], the USA [24] and Turkey [25]. Also considering the hypothesis of the EKC, many articles analyse the relationship between energy consumption, economic growth and CO_2 emissions, adding variables related to exports or imports, for example for the cases of the USA [26], China [27], Turkey [28], Kazakhstan [29], Sub-Saharan Africa countries [30], Malaysia [31] and Korea [32]. The relationship between carbon emissions, energy consumption and economic growth is also analysed for the cases of South Africa [33], Turkey [34], the EU members states [35], Indonesia [36], Korea [37], China and India [38–43] and worldwide considering several countries [44,45].

Following the same methodology, some papers were found that analyse the relationship between energy consumption and real GDP growth. Considering the different countries, studies were detected in the USA [46], China [47,48], Bangladesh [49], Iran [50], Turkey [51] and 11 oil exporting countries [52]. One of the articles examines the relationship between capital formation, energy consumption and real GDP in a panel of G7 countries [53].

The literature review shows that the different analyses of emissions seek to provide a theoretical basis to facilitate the development of policies aimed at reducing carbon without affecting economic growth. According to Eurostar, CO_2 emissions are an important contributor to global warming and they are influenced by factors such as climatic conditions, economic growth, population size, transport and industrial activity. Multiple factors can contribute to more or less emissions and as we have seen before, it is not clear to what degree imports and exports influence this accretion. This article takes a further step, analysing whether this influence really exists or not. In fact, it has a dual aim. First, it seeks to analyse how imports and exports influence the evolution of GHG emissions, and second it aims to find out if there is a cause and effect relationship between these emissions and employment. The analysis will be carried out for EU member countries (see Figures 1 and 2). The importance of the proposed analysis lies in gaining a better understanding of the impact produced by trade relations between countries and employment to be able to consider these effects when designing economic policies and proposing regulations to monitor, inform and quantify, helping to reduce the global level of emissions and achieve the goals established around the world.

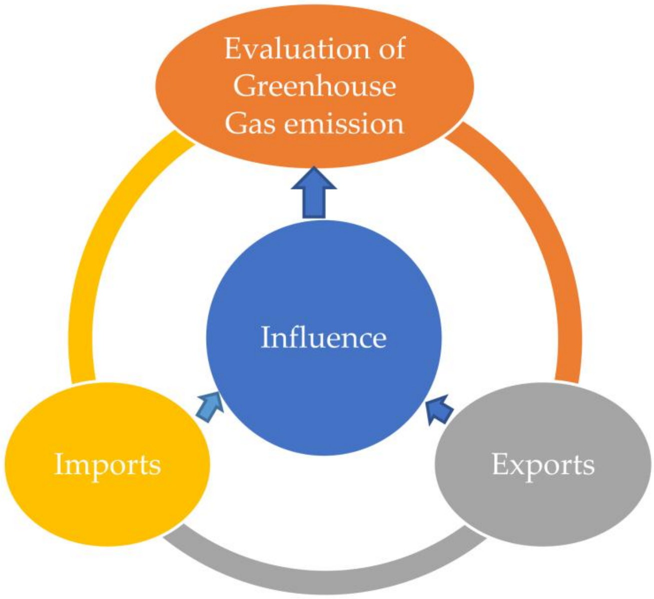

Figure 1. Objective 1.

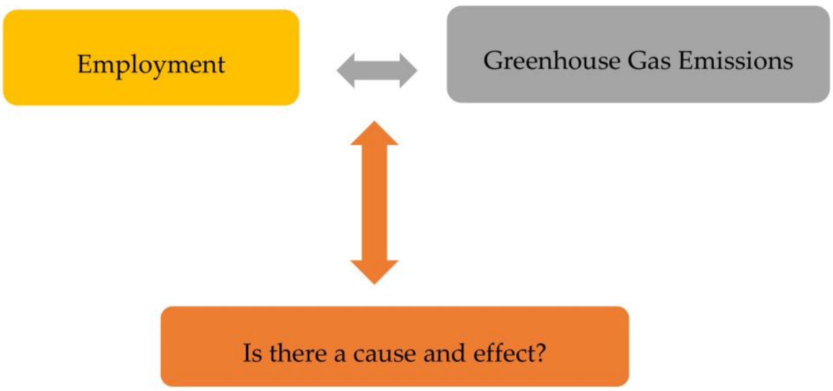

Figure 2. Objective 2.

2. Results and Discussion

Some descriptive statistics are shown in Tables 1 and 2. GHG emissions for the first year (1992) and the final year (2010) of our study are shown in Table 1. The countries with higher levels of GHG emissions in 1992 than in 1990 in decreasing order were Malta (115, CO_2 total equivalent, base 1990), Cyprus (111), Portugal (110), Denmark (107), Spain (105), France (103) and Switzerland (103). The countries with lower levels of emissions, also in decreasing order, were Lithuania (61, CO_2 total equivalent, base 1990), Estonia (68), Romania (71), Latvia (75), Bulgaria (75), Slovakia (81), Hungary (83) and the Czech Republic (84). While no systematic pattern was observed among countries with higher levels of GHG emissions in 1992 than in 1990, significantly, all the countries with lower emissions were ones with previously centralised economies that had recently been liberalised.

Table 1. Descriptive. Dependent variables.

CO_2 Total Equivalent	Base 1990			Millions of Tonnes	
	1992	2010	Variation	1992	2011
Belgium	100	92	−8.0%	143,796	131,782
Bulgaria	75	54	−28.0%	80,493	60,352
Czech Republic	84	71	−15.5%	165,609	137,423
Denmark	107	89	−16.8%	73,208	61,217
Germany	92	75	−18.5%	1,153,116	943,518
Estonia	68	50	−26.5%	27,348	19,989
Ireland	101	111	9.9%	56,020	61,493
Greece	101	113	11.9%	105,612	117,278
Spain	105	126	20.0%	297,083	348,641
France	103	93	9.7%	572,378	514,200
Italy	100	97	−3.0%	517,693	500,314
Cyprus	111	168	51.4%	6782	9444
Latvia	75	45	−40.0%	19,668	12,035
Lithuania	61	42	−31.1%	30,212	21,121
Luxembourg	102	94	−7.8%	13,222	12,252
Hungary	83	70	−15.7%	82,101	67,945
Malta	115	149	29.6%	2293	2998
Netherlands	102	99	−2.9%	215,082	209,177
Austria	97	108	11.3%	75,435	85,012
Poland	95	88	−7.4%	433,380	401,670
Portugal	110	118	7.3%	67,269	71,382
Romania	71	48	−32.4%	174,050	116,621
Slovenia	93	106	14.0%	17,202	19,482
Slovakia	81	64	−21.0%	58,271	45,896
Finland	95	106	11.6%	66,828	74,537
Sweden	100	91	−9.0%	72,518	65,487
United Kingdom	98	77	−21.4%	750,886	593,933
Iceland	93	130	39.8%	3246	4542
Norway	92	101	9.8%	45,964	53,896
Switzerland	103	108	4.9%	54,442	54,247

Source: OECD, Statistics Portal, 2016 [54].

Table 2. Descriptive. Imports and exports of goods and services and GDP per capita.

Country	Exports of Goods, Services (Millions of Euros)		Exports of Goods (Millions of Euros)		Imports of Goods, Services (Millions of Euros)		Imports of Goods (Millions of Euros)		GDP Per Capita (PPP)
	1997	2012	1997	2012	1997	2012	1997	2012	2012
Belgium	170,068.7	279,839.3	138,442.3	219,436.2	165,132.6	268,800	135,837.6	212,753.1	30,500
Bulgaria	7,745.5	17,693.3	4980.8	13,911	6071.9	19,932.8	4581.7	17,262.4	12,100
Czech Republic	31,252.1	103,967.7	23,403.5	89,387.5	33,608.2	91,970.3	28,191.6	79,153.9	20,200
Denmark	65,627.5	117,026.1	47,044.5	67,620.7	55,802.4	107,927.5	38,032.0	63,626.2	32,000
Germany	525,983.8	1,280,999.8	450,060.1	1,082,263	504,253.9	1,098,533.1	384,567.6	893,009.1	31,100
Estonia	4041.8	12,261.6	2455.1	9151.9	4109.0	11,910.2	3291.0	9729.4	17,500
Ireland	59,847.3	164,606.4	47,418.4	85,786.7	50,848.1	118,637.5	30,048.3	42,533.4	33,200
Greece	-	42,227.5	-	21,527.3	-	48,178.8	-	37,492.7	19,200
Spain	155,011.8	292,072.5	104,927.1	203,418.4	142,957.8	270,293.5	115,990.2	214,498.9	24,900
France	321,454.4	504,571.2	245,346.1	395,906.2	289,349.9	531,023.4	224,291.9	439,009.5	27,500
Italy	303,418.6	414,120.1	236,962.1	340,798.3	263,222.9	370,976.6	203,160.4	299,634.3	25,200
Cyprus	4846.5	7164.7	1246.3	1262.2	4894.2	7183.9	3507.6	4687.6	23,200
Latvia	3635.1	9036.7	2081.8	6459.2	3838.5	9734.9	3107.2	8315.4	-

Table 2. *Cont.*

Country	Exports of Goods, Services (Millions of Euros)		Exports of Goods (Millions of Euros)		Imports of Goods, Services (Millions of Euros)		Imports of Goods (Millions of Euros)		GDP Per Capita (PPP)
	1997	2012	1997	2012	1997	2012	1997	2012	2012
Lithuania	6603.1	20,304.1	5363.6	16,746.3	6770.2	19,264.4	5761.3	16,494.4	17,800
Luxembourg	24,966.4	59,452	7435.7	11,530	20,901.4	52,552.5	9894.5	20,040.5	69,400
Hungary	24,766.1	94,137.2	17,764.6	78,885.4	24,701.3	83,522.4	20,304.9	71,404.6	16,800
Malta	-	5237.3	-	2609.8	-	4895	-	3025.3	22,000
Netherlands	227,349.0	460,127	172,927.0	365,204	201,457.0	407,063	146,558.0	317,540	32,800
Austria	76,485.5	156,458.9	54,111.1	113,260.8	78,215.6	139,295.7	58,911.7	112,113	33,300
Poland	43,413.6	140,364	33,701.2	115,728.5	51,613.8	137,552.1	45,982.9	117,060.3	16,800
Portugal	30,821.3	55,550.5	24,064.0	41,128	39,368.8	56,456.8	33,511.8	48,212.1	19,200
Romania	11,027.2	38,586.9	9011.6	32,442.7	11,130.1	55,972	9110.7	49,998.1	12,600
Slovenia	9928.9	23,411.4	7734.4	19,200.9	10,196.1	21,317.8	8647.0	18,450.3	21,000
Slovakia	12,886.1	49,738	10,597.2	46,167.4	15,550.8	43,589.4	13,223.4	40,098.2	19,200
Finland	38,706.0	73,519.8	32,075.9	55,663.6	34,714.7	68,341.8	25,495.8	49,430	29,100
Sweden	88,253.3	175,379	68,521.9	12,2240	80,670.4	152,117.1	59,128.8	112,148.6	32,800
United Kingdom	34,7931.8	565,686.6	238,584.0	338,008.5	329,489.1	580,067	250,988.1	440,432.1	28,400
Iceland	2837.7	5817.7	1964.1	3504.5	2840.9	4586.1	2064.8	2675.2	28,700
Norway	95,701.2	104,316.9	75,268.9	75,527.9	50,621.2	86,102.2	32,751.2	56,011	49,900
Switzerland	101,485.8	191,013	73,213.3	136,455	88,621.5	156,529.8	75,086.6	124,688.6	40,800

Source: Eurostat, 2016 [55].

A closer look at the variations in emissions between 1992 and 2010 in comparison to 1990 may yield more interesting results. 12 of the 30 countries analysed had higher level of emissions, most notably (in decreasing order), Cyprus (an increase of 51.4%), Iceland (39.8%), Malta (29.6%) and Spain (20.0%), while eight other countries' emissions increased by less than 15%. On the other hand, the greatest decrease between 1992 and 2010 in relative terms was Latvia (a variation of −40.0%) followed by Romania (−32.4%), Lithuania (−31.1%), Bulgaria (−28.0%), Estonia (−26.5%), the United Kingdom (−21.4%) and Slovakia (−21.0%). In the rest of the countries the decrease was less than 20%. As can be seen there is an asymmetry both in the sense of the variation—many more countries are reducing their emissions than increasing them—and the magnitude, as the reductions are much greater in relative terms than the increases.

The results of the estimation of the models are shown in Tables 3 and 4. It can be seen that it was the imports and exports of goods rather than the imports and exports of services that were related to CO_2-equivalent levels, both in terms of millions of tonnes and the index. Note that in both cases, the imports and exports of goods were very inelastic, and while this was less so in the case of the index (Table 3) it was not statistically different, with 95% credible intervals overlapping. Note that the increase in exports of goods reduced levels of CO_2-equivalent, while imports of goods increased them. Also note, however, that in terms of absolute value, we could not reject that elasticities of imports and exports (of goods) were statistically different.

In both cases, millions of tonnes of CO_2-equivalent and the index, the economic crisis was associated with a close to 7% decrease in levels, with a 95% credibility interval from −2% to −11%. Only in the case of millions of tonnes of CO_2-equivalent was employment related to a reduction in CO_2-equivalent levels with reductions of between 0.63% and 0.70% for each one per cent increase in employment (in all cases, employment in males, females and total).

Table 3. Results of the estimation of the models with dependent variable CO_2 total equivalent.

Variables	Elasticities	Standard Deviation	95% Credibility Interval	
			Lower	Upper
Exports of goods	−0.0832	0.0251	−0.1325	−0.0339
Imports of goods	0.0770	0.0243	0.0292	0.1249
Exports of goods and services	−0.0301	0.0416	−0.1118	0.0517
Imports of goods and services	0.0269	0.0413	−0.0542	0.1080
GDP per capita	0.0007	0.0024	−0.0041	0.0054
Employment	-	-	-	-
Total	−0.0066	0.0036	−0.0136	0.0003
Males	−0.0063	0.0034	−0.0131	0.0004
Females	−0.0070	0.0037	−0.0143	0.0003
Economic crisis indicator	−0.0736	0.0218	−0.1169	−0.0304

Shaded grey, the 95% credibility interval did not contain the unity (i.e., statistically significant at 95%). In yellow, the 90% credibility interval did not contain the unity (i.e., statistically significant at 90%).

Table 3. *Cont.*

Random Effects Standard Errors	Mean	95% Credibility Interval	
		Lower	Upper
Gaussian observations	0.0933	0.0883	0.0989
Country-specific heterogeneity	1.6369	1.3472	2.0602
Non-linear trend	0.0184	0.0106	0.0410

Deviance Information Criterion (DIC): −1174.26; Effective number of parameters: 45.97; Watanabe-Akaike information criterion (WAIC): −1166.69; Effective number of parameters: 49.73.

Table 4. Results of the estimation of the models with dependent variable, CO_2 total base 1990.

Variables	Elasticities	Standard Deviation	95% Credibility Interval	
			Lower	Upper
Exports of goods	−0.0672	0.0238	−0.1140	−0.0204
Imports of goods	0.0610	0.0231	0.0156	0.1064
Exports of goods and services	0.0009	0.0407	−0.0791	0.0808
Imports of goods and services	−0.0043	0.0403	−0.0836	0.0750
GDP per capita	0.0030	0.0023	−0.0015	0.0074
Employment	-	-	-	-
Total	−0.0040	0.0034	−0.0106	0.0027
Males	-	-	-	-
Females	-	-	-	-
Economic crisis indicator	−0.0696	0.0212	−0.1125	−0.0284

Shaded grey, the 95% credibility interval did not contain the unity (i.e., statistically significant at 95%).

Table 4. *Cont.*

Random Effects Standard Errors	Mean	95% Credibility Interval	
		Lower	Upper
Gaussian observations	0.0901	0.0850	0.0957
Country-specific heterogeneity	0.1080	0.0647	0.1757
Non-linear trend	0.0151	0.0079	0.0387

Deviance Information Criterion (DIC): −1115.77; Effective number of parameters: 43.10; Watanabe-Akaike information criterion (WAIC): −1109.36; Effective number of parameters: 45.98.

Regarding the interpretation of random effects, there is an important heterogeneity between countries (compare the typical variations of county-specific random effects and Gaussian observations), which is even more important, as is to be expected, when considering the total equivalent CO_2 in millions of tonnes. Temporal heterogeneity, however, was much lower (the typical variation of the non-linear trend in relation to that of the Gaussian observations).

In recent times, variations in emissions have been related to the demographic growth of the population and, especially, with worldwide economic growth. However, multiple factors may contribute to higher or lower emissions, for example the technology and type of energy used, the provision of resources, institutional structures, employment levels, transport models, lifestyles and international trade [56].

As can be seen, the factor that contributes most to explaining the high levels of emissions in the richest countries is their GDP per capita, while in the case of developing countries their poverty explains why their levels of emissions are much lower. One explicative factor could be that the variation in emissions in these cases is determined largely by the energetic intensity and the combination of energies for each country. It is also important to point out that emissions in relation to these factors can vary enormously between countries.

In light of these results, it can be stated that when there are more imports, emissions increase. An explicative effect for this in the case of Spain could be, for example, that these emissions are directly linked with burning coal in thermal power stations for electricity generation. Despite the economic crisis, emissions have significantly increased due to the fact that 22% more carbon was burned in 2015 than in 2014. Consequently, coal imports have grown because foreign coal is cheaper and also the cost of coal per tonne has gone down enormously in recent times [57].

Another significant result of this study is that when there are more exports there are fewer emissions. This result could be explained in part by the fact that what many of these countries do when they are exporting in order to be able to carry out this process is foster an increase in imports of intermediary products and raw materials. Furthermore, this explanation could be linked to the previous result. These results suggest the need for a detailed analysis of the ultimate reasons for these behaviours.

It is also important to point out that when there is high employment there is more energy consumption and higher levels of GHG emissions. However, it must also be said that emissions decreased throughout 2015 and 2016, largely because of greater energy efficiency and an upsurge in renewable energies.

This study shows that many of the countries analysed need to adopt more policies to reduce emissions and they must also rethink existing policies even if this means opposing their social development policies, since there is a strong relationship between economic growth and consuming natural resources. A mutual bond between economic behaviour and consuming resources thus needs to be established to create a better development model for the societies of these countries and to lessen the harm done to the environment.

Measures related to controlling carbon emissions both in each country and internationally must be taken, but without neglecting economic growth. To meet these objectives, it is essential to reduce energy consumption and promote the innovative use of clean energies.

Last, it should be noted that all economic agents (producers, consumers, workers, etc.) must contribute to reducing GHG emissions because ultimately we are all responsible for emissions, be it directly or indirectly.

3. Material and Methods

3.1. Data Sources

We use data related to CO_2-equivalent published by The Organisation for Economic Co-operation and Development (OECD) on OECD.Stat [54]. This organization publishes data and metadata for OECD countries and selected non-member economies to help governments foster prosperity and fight poverty through economic growth and financial stability, and also to help ensure that the environmental implications of economic and social development are considered. Regarding the information about our variables of interest, we use Eurostat [55], the statistical office of the EU, which provides high quality statistics for Europe that enable comparisons between countries and regions.

3.2. Variables

Our interest was to evaluate the influence of imports and exports of goods and services on GHG emissions in a number of countries. To do so, we set up a data panel composed of 30 countries over 21 years, from 1992 to 2012 (see Table 1).

Emissions of greenhouse gases were measured by carbon dioxide equivalent (CO_2-equivalent). As is known, CO_2-equivalent is a measure of CO_2 used to compare emissions based on their global warning [13]. In fact, we used two measures of CO_2-equivalent, millions of tonnes and an index, (1990 = 100).

Our explanatory variables of interest were imports and exports of goods and imports and exports of goods and services (millions of euros, base 2005). In the models we included as control variables the GDP per capita (Purchasing Power Standard), employment (in percentage over the active population), an indicator of the economic crisis and a trend. The indicator of the economic crisis was a dummy variable taking the value one from 2008 and zero otherwise. We specified a non-linear trend, approximated by random effects associated with a trend (1, 2 . . . , 21). Both the dependent variables and the explanatory variables (of interest and control variables) were log transformed (see Figure 3).

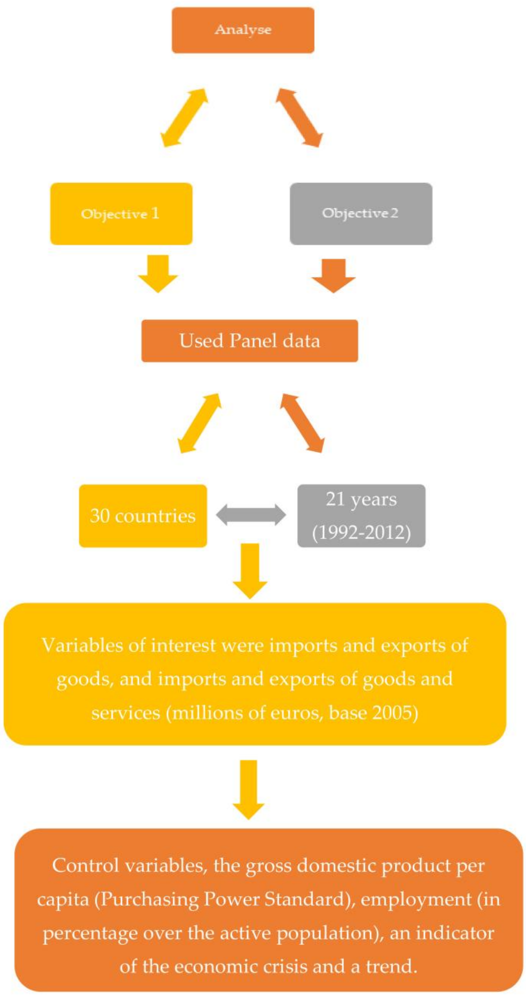

Figure 3. The model.

3.3. Model

We have a complex model with panel data structure, heterogeneity, spatial adjustment, and so on, so we have performed the inferences using a Bayesian framework. This approach (more or less pure) was considered the most suitable to account for model uncertainty, both in the parameters and in the specification of the models for cross-sectional studies or in panel data models [58,59]. Furthermore, only under the Bayesian approach was it possible to model both heterogeneity and temporal extra variability. Last, within the Bayesian approach, it is easy to specify a hierarchical structure on the (observable) data and (unobservable) parameters, all of which are considered random quantities [60]. Within the (pure) Bayesian framework, we followed the Integrated Nested Laplace (INLA) approach [60]. The random effects were modelled by a random walk of order 1 (i.e., independent increments) for the Gaussian random effects vector [61]:

$$\Delta v_{jt} = v_{jt} - v_{jt+1} \quad \Delta v_{jt} \sim N\left(0, \sigma_v^2\right)$$

Possible country-specific heterogeneity was allowed, including in the model random effects associated with the intercept. In this case, random effects were distributed as independent and Gaussian distributed random variables [62]. We used penalising complexity priors, which are invariant to reparameterisations and have robustness properties [63]. All the analyses were carried out with the free software R (version 3.2.3) [64] though the INLA library [65,66].

4. Conclusions

This study aimed to evaluate the effect of imports and exports of goods and services on GHG emissions in a data panel composed of 30 countries over 21 year. A Bayesian framework was used for the analyses, which were carried out with software R (version 3.2.3). Our explanatory variables of interest were imports and exports of goods and imports and exports of goods and services (millions of euros, base 2005). In the models we included as control variables, the gross domestic product per capita (Purchasing Power Standard), employment (in percentage over the active population), an indicator of the economic crisis and a trend.

According to our knowledge, this is the first study to investigate these three variables and their relationship with emissions. Based on the results obtained, we can draw several conclusions and consider some political implications to improve the environment.

The results show that there are relationships between imports, exports, employment and GHG emissions. First, emissions were shown to grow when there are more imports and decrease with higher exports. Second, higher levels of employment were seen to imply higher GHG emissions. Another result of this study was that the factor that most contributes to explaining the high level of emissions in the richest countries was shown to be their GDP per capita, while in the case of developing countries their poverty explains why their levels of emissions are much lower. Note, however, that in terms of absolute values, we could not reject that elasticities of imports and exports (of goods) were statistically different. It is also important to note that when there is a high level of employment there is more energy consumption and higher levels of GHG emissions.

Carbon emissions arise from the economic activities carried out, as well as from higher production and consumption, and they have increased because of globalization. In light of this situation and considering that the current environmental problems extend beyond existing borders between countries, this is a subject that calls for dialogue and a joint commitment. This research promotes the need to develop policy and strategy frameworks that include the collaboration of all countries to address environmental problems. In addition, disseminating information and environmental education is very important to provide these implemented policies with the support they require. Any decision on regulations or policy taken must be done so strategically to ensure that emissions do not increase beyond current levels, but in fact decrease without compromising economic growth. For this, it is important to analyse each country and have international cooperation, since economic growth is a key factor for countries, and in particular those that are developing, so the search for sustainable growth must be encouraged.

The results presented show that there is a need to continue researching in this field as this is currently a very important issue that must be addressed in various ways to achieve the environmental objectives set. For example, in future research other impact variables could be analysed to see the effect they have on the environment, so that in the long term the greatest number of existing negative impacts can be known and their effects on climate change mitigated. Examples could be considered with respect to possible solutions for imports and exports to diminish these effects, in terms of both diversification of products and solutions for their production and transport. How technology and the type of energy used, the provision of resources, institutional structures and lifestyles cause greater or lesser increases or decreases in emissions could also be studied in greater depth.

Last, it is important to note that in a globalized world where international trade is on the increase, it is not fair that responsibility for GHG emissions does not consider the final destination of the goods produced. Therefore, another line of research would be to better analyse how GHGs are distributed or assigned among the countries of the world to allow us to better quantify each country's responsibility regarding emissions. Two aspects need to be considered for this analysis. The first would be more based on the production or emissions made in a territory, where each country would be responsible for the emissions generated or produced within its borders. And the second possible serious approach would be to analyse the emissions footprint, where each country would be responsible for all the emissions associated with generating the goods and services they demand, regardless of where they were produced. In this way, each country would be responsible for the emissions contained in its consumption.

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