THE ATMOSPHERIC EMISSIONS IN SPAIN: A REGIONAL ANALYSIS

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ABSTRACT

The gas emissions to the atmosphere are one of the main and more actual environmental problems in the world. The effects of greenhouse gas emissions have been studied and treated recently in the Climate Change Conference in Kyoto. In the approved Kyoto Protocol, the European Union would reduce emissions by 8%, the United States by 7%, and Japan by 6%. The data for each country are used to implement policies and to make global decisions regarding the level of emissions allowed in the future. For this reason, a study more in depth about the origin and level of emissions from a regional perspective become necessary, due to the implications on the regional development.

In this paper we will provide detailed information regarding atmospheric emissions in Spanish regions. Moreover, we will show that in many cases the atmospheric emissions are not directly related to the economic situation of each region. For this reason, environmental policies should pay attention to the regional differences within a country.

K.W.: Atmospheric emissions, Spain.

1 INTRODUCTION

Within the European Union (EU), there is a concern for the protection of the environment. Very few environmental problems are wholly national in origin or in their effects. For this reason, environmental protection measures should be consistent between the countries of the EU, because national differences in environmental legislation could rise technical barriers to trade.

Moreover, it is convenient to study the damage of ecosystems by human activities (mainly industrial) in order to get information that help to design policies and strategies oriented to reduce the environmental pollution. It would also be interesting to value the cost/profit of the application of different corrector measures in the control of emissions.

Since the beginning of 80's, due to awareness of the negative environmental effects of economic activities, the European Union has been working in the compilation of an European emission inventory data base. This inventory was established as part of the CEC CORINE project with the object of developing a mechanism for generating comparable, transparent, and verifiable emissions inventories with a very detailed breakdown of sources activities, including specific estimates of emissions from large point sources (EUROSTAT 1995).

The major pollutants contributing to air quality problems at local, national and international levels are the emissions of sulphur dioxide (SO_2), nitrogen oxide (NOx), volatile organic compounds (VOC), carbon monoxide (CO), carbon dioxide (CO_2) , methane (CH_4), nitrous oxide (N_2O) and ammonia (NH_3).

Among EU countries, Spain occupies the fourth place in SO_2 and N_2O emissions, the fifth in NO_x , VOC, CO and CO_2 , and the sixth in CH_4 and NH_3 (CORINAIR 1990)[1]. Therefore, it is clear that Spain is an important emission producer and deserves a deep analysis. However, due to the different economic conditions of Spanish regions, it is interesting to account for their emission peculiarities as well as to analyse the relation with socio-economic variables, such as population, energy, GDP, etc.

[1] In Spain, there are five emission inventories with 1985, 1990, 1991, 1992 and 1993 as base years.

The aims of this paper are to examine the atmospheric emissions by Spanish regions in 1993, to identify the main source sectors, and to provide the relationship with some economic measures.

2 ATMOSPHERIC EMISSIONS IN SPAIN: A REGIONAL DESCRIPTION

Figure 1 presents the emissions of the major pollutants contributing to air quality problems at local, national and international levels: SO_2, NOx, VOC, CH_4, CO, CO_2, N_2O, and NH_3. Carbon monoxide (5 Mt.), methane (3 Mt.) and sulfur dioxide (2 Mt.) are the main Spanish emissions to the atmosphere.

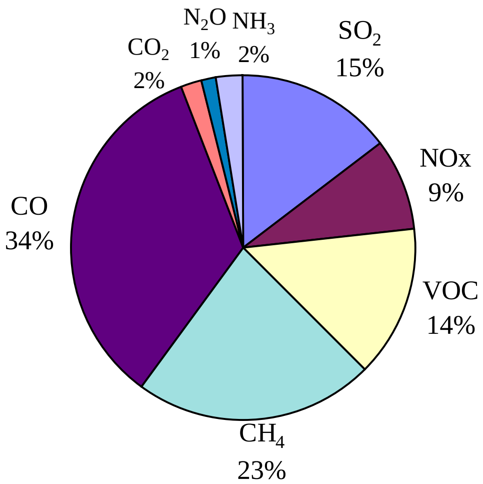

Figure 1: Spanish emissions: Distribution by contaminants. 1993.

Although, the full SNAP (Selected Nomenclature for Air Pollution) activity nomenclature includes some 250 headings, for the purpose of reporting and presentation, only eleven aggregated source groups are used. Each sector contribution to global Spanish emissions in 1993 is showed in Table 1. An common aspect to point out is the high concentration of emissions by sector.

Table 1: Spanish emissions by sector (%). 1993.

SECTOR	SO_2	NOx	VOC	CH_4	CO	CO_2	N_2O	NH_3
01	62.49	20.58	0.52	0.29	0.41	24.37	4.73	0.00
02	3.72	1.82	2.89	1.31	17.99	10.92	1.29	0.00
03	23.42	13.69	0.61	0.23	8.19	23.86	3.35	0.00
04	2.85	0.85	3.88	0.13	4.84	5.78	3.49	3.02
05	0.00	0.00	3.04	20.65	0.00	0.00	0.00	0.00
06	0.00	0.00	15.95	0.00	0.00	0.00	0.00	0.00
07	3.29	42.99	25.33	0.41	56.90	18.60	1.19	0.32
08	2.68	18.37	2.04	0.05	2.35	4.92	0.18	0.01
09	1.55	1.27	2.60	20.59	6.55	2.92	0.25	0.00
10	0.00	0.07	4.00	29.33	2.53	5.31	30.65	96.66
11	0.00	0.36	39.14	27.01	0.24	3.33	54.88	0.00
TOTAL	100	100	100.00	100	100	100	100	100

Source: CORINAIR Inventory.

Note: 01 Public power, cogeneration and district heating. 02 Commercial, institutional and residential combustion plant. 03 Industrial combustion. 04 Production processes. 05 Extraction and distribution of fossils fuels. 06 Solvent use. 07 Road transport. 08 Other mobile sources and machinery. 09 Waste treatment and disposal. 10 Agriculture. 11 Nature.

SO_2 is mainly generated by group 1 (electricity and heat generation) and group 3 (industrial combustion). Regarding NOx, transportation (groups 7 and 8) represents 60% of emissions, corresponding more than 40% to fuel combustion in motor vehicles (road transport). Moreover, electricity and heat generation (group 1) and the rest of industrial sectors represent one third of total NOx emissions. Volatile organic compounds (VOC) emissions are originated mainly by nature (39%), combustion in motor vehicles (25%) and solvent use (16%). On the other hand, more than 50% of carbon monoxide (CO) emissions are originated by fuel combustion in motor vehicles (group 7). Carbon dioxide (CO_2) emissions are related to industrial sector using carbon-based fossils fuels. In fact, as showed in Table 1, more than 50% of carbon dioxide (CO_2) emissions are due to sector 1, 3 and 7.

Agriculture, nature and waste are the three main anthropogenic methane (CH_4) emission sources in Spain. They are estimated at 29%, 27% and 21% for the year 1993, respectively. Also nitrous oxide (N_2O) and ammonia (NH_3) are concentrated in agriculture and nature. These emissions come mainly from the anaerobic enteric fermentation (digestion) of animals, from the anaerobic management of the animal wastes, and from the anaerobic fermentation of organic matter trapped in landfills. Being radiatively active, methane traps infrared radiation or heat and contributes to the warming of the Earth.

After analysing the Spanish emissions as a whole, it is interesting to investigate how the emissions are distributed by regions. Hereafter, we will only pay attention to those contaminants originated by industrial activities and with a special importance in terms of emissions: sulphur dioxide (SO2), nitrogen oxide (NOx), volatile organic compounds (VOC) and carbon monoxide (CO).

In 1993, Galicia generated almost 30% of SO_2 Spanish emissions, followed by Aragón (19%) (Figure 2). It should also be noted that the data for Galicia (567,000 T) are the greatest if compared with any other emission and region. It is easy to identify the reason for this situation, great part of Spanish electricity is produced in thermal power plants located in the regions mentioned above.

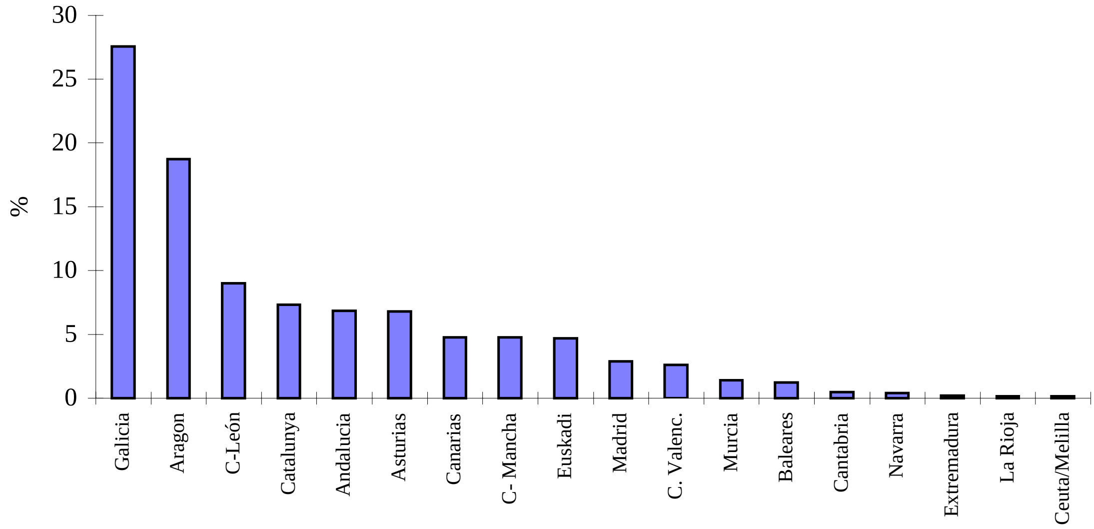

Figure 2: SO_2 emissions: distribution by regions. 1993.

Moreover, it can be showed that the origin of sulphur dioxide diverges by regions (Table 2). In fact, more than 60% of SO_2 emissions are caused by sector 1 in six regions (Aragón, Galicia, Ceuta/Melilla, Castilla y Leon, Illes Balears and Asturias). While in the rest, the main source of SO_2 is industrial combustion and processes. SO_2 emissions from stationary combustion sources depend heavily on the sulphur content of the fuel, which varies significantly between regions. As it was mentioned above, Galicia and Aragon stand out by the importance of sector 1 in SO_2 emissions, with more than 90% of their respective total SO_2 emissions.

Regarding NOx, Andalucia represent the highest participation in Spanish emissions (13%), followed by Catalunya (12%), and Castilla y Leon (11%) (Figure 3). Once again, although the remaining regions show almost the same participation in atmospheric emissions, the source sectors are different. For example, NO_x emissions from stationary combustion sources depend not only on the fuel type but also on combustion mode, burner type, and combustion temperatures; this influences the emissions significantly in a very complicated way so that emissions factors come by as much between fuels as between sector.

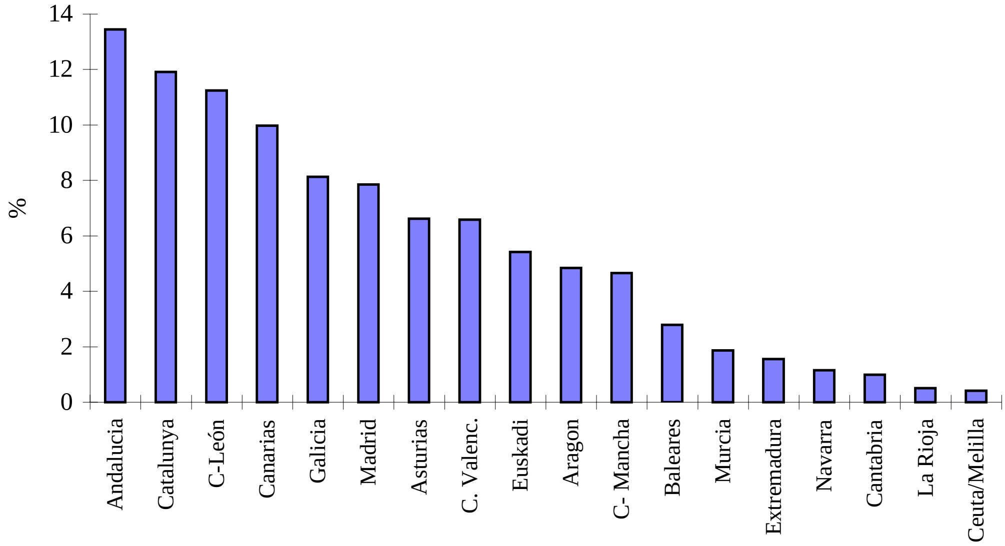

Figure 3: NOx emissions: distribution by regions. 1993.

According to Table 2, there are regions with NO_x emissions caused mainly by only one sector. Sector 1 (public power, cogeneration, and district heating) is the main source in five regions: Aragón, Castilla y León, Asturias, Illes Balears, and Ceuta/Melilla. While, transportation (Sectors 7 and 8) is the principal origin of NOx pollution in most regions: Andalucia, Madrid, Comunidad Valenciana, Murcia, Catalunya, La Rioja, Extremadura, and Canarias. By contrast, NOx emissions are equally generated for three sectors (power plants, road traffic and industrial combustion) in several regions (Galicia, Castilla-La Mancha, and Cantabria).

Table 2.- Regional emissions classified by contaminants and main source sector. 1993.

	SO_2		NOx		VOC		CO	
	Sector	(%)	Sector	(%)	Sector	(%)	Sector	(%)
ANDALUCÍA	03 01	(47,42) (27,41)	07 08	(51,59) (15,05)	11 07	(47,05) (20,54)	07 02	(63,95) (17,93)
ARAGÓN	01	(96,62)	01 07	(45,03) (26,04)	11 07 (14,81))	(54,89)	07 02	(50,83) (17,18)
ASTURIAS	01 03	(66,27) (24,16)	01 03	(52,96) (21,02)	07 11	(32,83) (17,63)	03 04	(41,34) (18,06)
CANTABRIA	03	(72,88)	07 03 08	(48,45) (26,87) (18,81)	11 07 06	(34,18) (22,98) (19,81)	07 04 02	(35,92) (34,20) (23,27)
CAST Y LEÓN	01	(83,77)	01 07 08	(51,76) (21,86) (16,85)	11 07 06	(51,98) (15,36) (13,37)	07 02	(37,78) (27,88)
CAST-LA MANCHA	03 04	(60,76) (19,32)	07 08 03	(35,07) (27,73) (25,65)	11	(66,06)	07 02	(40,61) (15,81)
CATALUNYA	03 01	(53,47) (17,35)	07 03	(63,67) (19,21)	07 11	(32,81) (25,50)	07 02	(73,45) (13,94)
C. VALENCIANA	03 07	(69,82) (12,54)	07 03	(66,39) (17,25)	07 11	(33,19) (26,92)	07	(77,98)
GALICIA	01	(90,94)	01 07 08	(29,89) (29,80) (29,61)	11 07 06	(41,86) (20,47) (16,52)	07 02	(44,06) (41,09)
MADRID	03 02	(48,92) (32,11)	07	(82,17)	07 06	(59,20) (22,64)	07	(84,87)
NAVARRA	03 02	(62,22) (19,71)	07 08	(49,39) (21,52)	11 07	(48,50) (14,89)	02 07	(56,61) (28,31)
EUSKADI	03 09	(67,97) (12,84)	07 03	(39,02) (37,28)	07 06	(32,84) (26,48)	07 03	(40,47) (30,17)

In relation to VOC, Andalucía and Catalunya present the highest level of emissions (40% of total) (Figure 4). While the remaining regions suppose an inferior participation. On the other hand, regions can be divide in two groups based on the origin sector: a) Regions with an important agrarian sector (Extremadura, Castilla-La Mancha, Aragón, and Castilla y León) and emissions originated mainly by nature (sector 11); b) Regions with an economy based on industrial activities and heavily populated (Madrid, Euskadi, Comunidad Valenciana, and Catalunya) and emissions generated by solvent use and road transportation (sector 6 and 7).

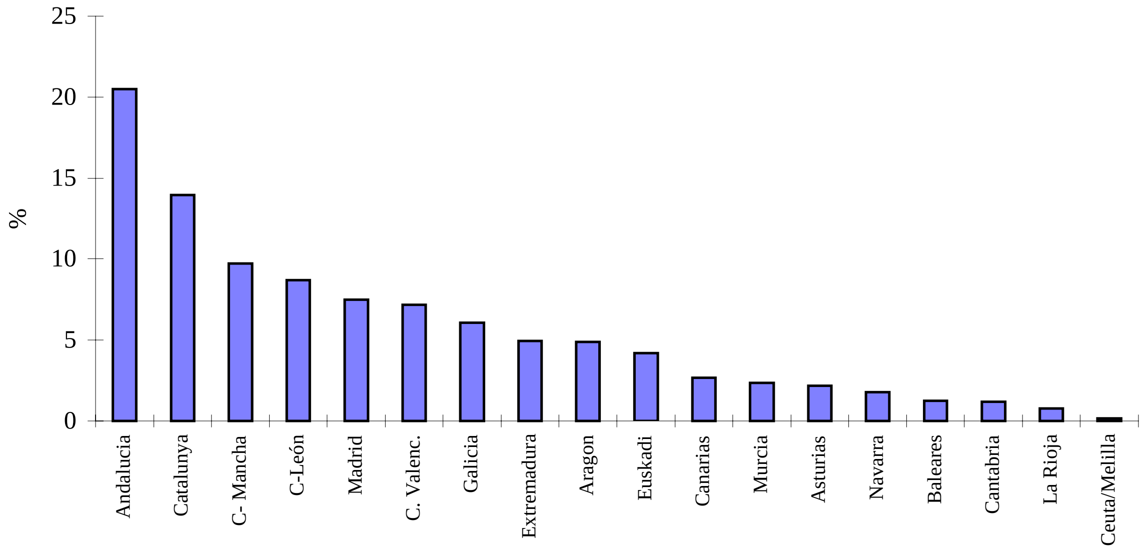

Figure 4: VOC emissions: distribution by regions. 1993.

Finally, with regards to CO, Andalucia, Madrid, and Catalunya account for the highest emissions (Figure 5) due to the great importance of road transport. In fact, sector 7 is the main origin in all regions (Table 2). It is necessary to point out that sector 3 (industrial combustion) is also an import source of this contaminant in Asturias.

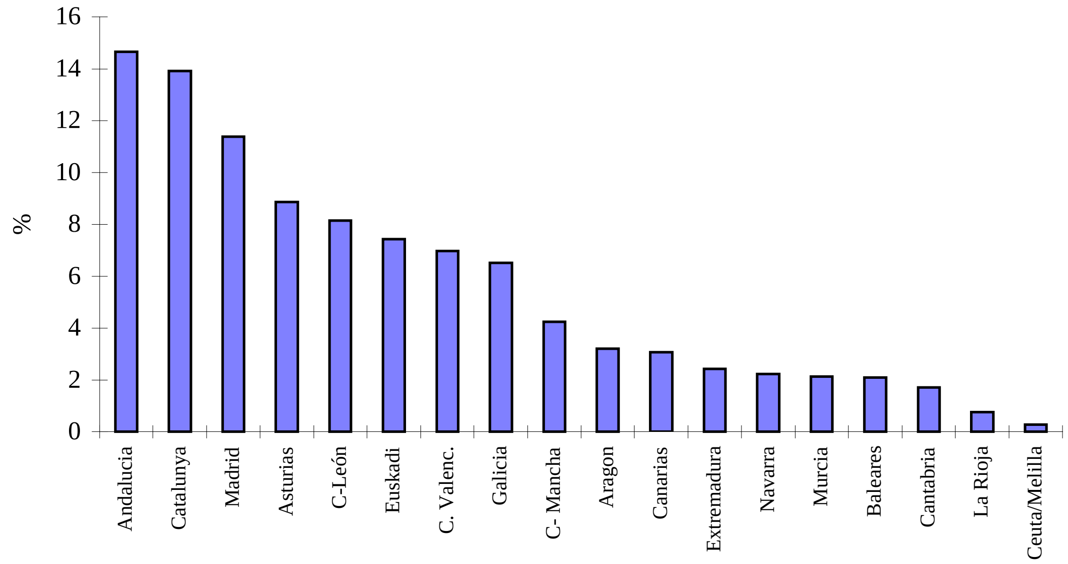

Figure 5: CO emissions: distribution by regions. 1993.

3 CLASSIFYING REGIONS BY EMISSIONS

As we could confirm in the last section, since the detailed allocation of industries may vary, the structure of the individual Spanish regions are not uniform. It should be clear that the successful development of Spain will depend to a great extent on the economic and ecological success of the regions. In the following, as we mentioned before, we focus our study in the more relevant emissions for Spain, that is, sulphur dioxide (SO_2), nitrogen oxide (NOx), volatile organic compounds (VOC), and carbon monoxide (CO).

In section 2, we have described each region participation in total Spanish emissions. At that point, we could observe many differences among regions regarding the kind of contaminants they generate. Then, it would be very interested, not only the study of contaminants generation in volume, but also the relation between this variable and the economic activity of regions, as well as their level of development.

A first approach is carried out by comparing the relative situation of each region in the volume of emissions per capita and some economic indicator, namely “Total Value Added per capita”. The statistical source used for latter has been Banco Bilbao-Vizcaya (BBV 1993).

Since sulphur dioxide and carbon monoxide are the most important contaminants in Spain (in volume), we have decided to present the following graphs just for them. Moreover, it seems also interesting to compare SO_2 emissions with other indicator, such as the “Value Added per capita generated by the energy sector” because sector 1 (power plants) is the main source of this contaminant in Spain.

Figure 6, for example, shows the relation between SO_2 emissions per capita and Total value added per capita. Although, most regions are close to the Spanish average in terms of contaminants, three regions, Aragón, Galicia, and Asturias, present the highest emissions per capita. Although, for Aragón, this situation have correspondence with a higher Total value added per capita, Galicia and Asturias stand out for having higher emissions per capita than Spain but lower total value added. It means that these two regions have not a great importance in terms of economic activity, but there is a heavy location of polluting industries in both regions, mainly related with energy production. On the other hand, more developed regions

(Catalunya, Madrid, and Euskadi) present a higher value added and a lowest SO_2 emissions per capita than the Spanish average (quadrant IV). This could be considered the optimal situation if compared with those regions located in quadrant II.

On the other hand, it was also considered the relation between regional emissions per capita and regional value added in energy sector (sector 1) per capita, due to its importance in SO_2 emissions (Figure 7). The situation is similar to that described for total value added, with the exception of Asturias (situated in quadrant I). For this region, higher value in volume of emissions is related to a higher energy value added than the Spanish average. It is obvious that this situation requires a deeper analysis in the future, since other important energy producer (Galicia) does not change the situation with respect to Figure 6.

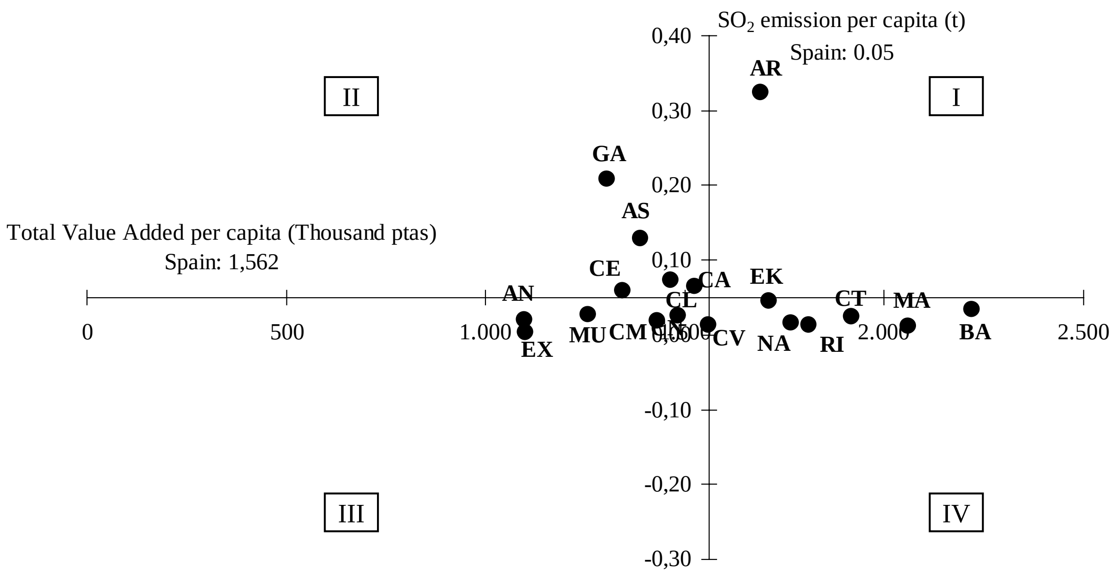

Figure 6: SO_2 emissions per capita vs. Total value added per capita, by region. 1993.

Legend:			
	AN: Andalucía	*AR: Aragón*	*AS: Asturias*
	BA: Baleares	*CA: Canarias*	*CN: Cantabria*
	CL: Castilla y León	*CM: Castilla-La Mancha*	*CT: Catalunya*
	CV: C. Valenciana	*EX: Extremadura*	*GA: Galicia*
	MA: Madrid	*MU: Murcia*	*NA: Navarra*
	EK: Euskadi	*RI: La Rioja*	*CE: Ceuta/Melilla*

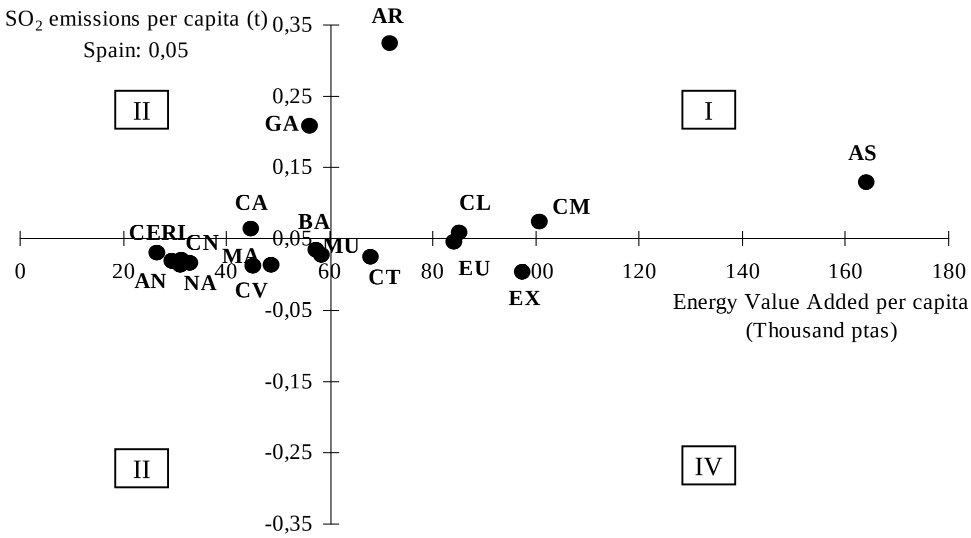

Figure 7: SO_2 emissions per capita vs. Value added (Energy sector) per capita, by region. 1993.
Note: See Figure 6.

Figure 8 shows the relationship between CO emissions per capita and total value added per capita. It is noted the anomalous behaviour of Asturias (quadrant II). Its high volume of emissions is generated mainly by sectors 3 (industrial combustion). Then, it is justified neither by its total value added per capita nor by its traffic intensity. The situation of remaining regions is quite similar to that observed for SO_2. Again, the most developed regions are situated in quadrant IV, close to the Spanish emissions average and with a higher value added.

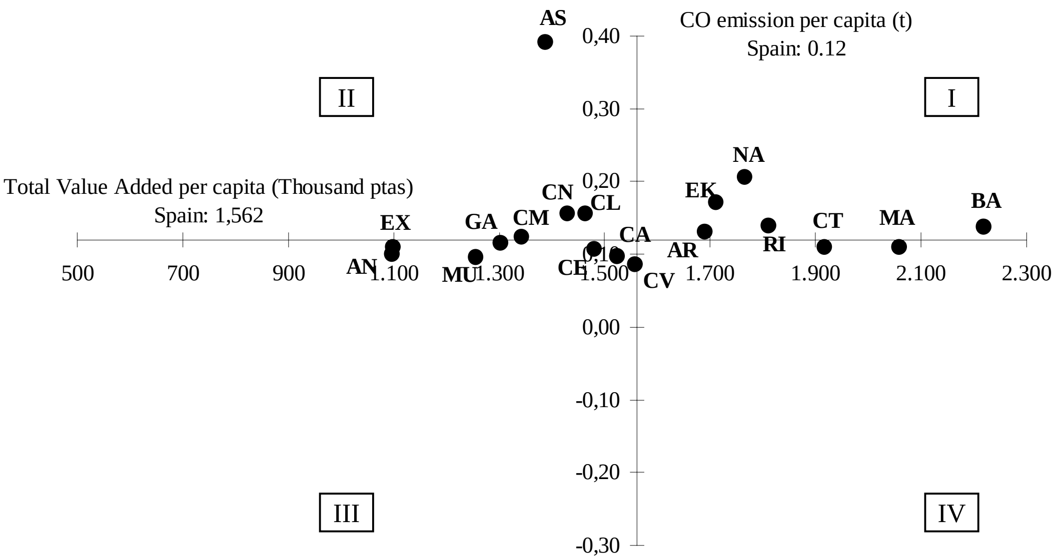

Figure 8: CO emissions per capita vs. Total value added per capita, by region. 1993.
Note: See Figure 6.

As it was shown, it is not only important to study the volume of emissions by region, but also to consider the level of economic development and the type of industrial activities located in each region. A more deeper study is needed in order to differentiate between the contamination due to high industrial development and that due to the location of pollutant activities,. In the following, we apply the methodology developed by Alcantara (1996) to analyse the regional contamination in 1993.

In recent studies, it is usual to calculate the contaminant intensity of a region (E_j^k) as the volume of emission of a certain pollutant k by unit of GDP. This measure has important limitations as global indicator because it implies a great simplification of a complex phenomenon. A high value of this ratio, above the average, could occur even in those regions with a relatively low volume of emissions, originated by polluting activities, and a low capacity of production.

In order to improve this approximation, Alcántara (1996) measures the impact of the regional contaminant intensity in relation to the contaminant intensity of the total territory (system), paying attention to the regional economic development of the regions and the regional polluting intensity.

Then, the contribution of region j to the generation of pollutant k in relation to the system average have the following expression:

$$E_j^k - E^k P_j^* = E^k\left(P_j - P_j^*\right) + \left(E_j^k - E^k\right)P_j^* + \left(P_j - P_j^*\right)\left(E_j^k - E^k\right) \quad (1)$$

where:

$E^k P_j^*$ is the average contribution of each region to the system, assuming an equal distribution of GDP (P_j^*) (according to the population share of region j on the system population).

$E^k\left(P_j - P_j^*\right)$ is the contaminant intensity effect. It represents the effect that on the average contaminant intensity (E^k) has the difference between the real economic development of the region (Pj) and that occurred in case of an equal distribution of GDP (P_j^*).

$\left(E_j^k - E^k\right)P_j^*$ is the capacity of production effect. It shows the effect of the difference between the regional and the average contaminant intensity on an equal distribution of GDP.

$\left(P_j - P_j^*\right)\left(E_j^k - E^k\right)$ represents an interaction effect.

Region *j* will contribute to the generation of contaminant *k* more (less or equal) to the system average, when $E_j^k - E^k P_j^*$ is positive (negative or zero). The decomposition of the regional contribution to the total contaminant intensity allows to establish a classification of the eighteen Spanish regions.

Tables 3-6 reflect the regional situation showing different patterns. Almost all regions situated in quadrant III have a negative net effect due to the low contaminant intensity compensating the positive effect due to its economic development. We could classified it as the best situation. On the opposite side, quadrant I could indicate the worst situation. In general, regions located on this quadrant have a positive net effect due to a high contaminant intensity and a low economic development.

On the other hand, quadrant II shows regions with a positive effect both in terms of contaminant intensity and economic capability, by contrast with quadrant IV.

Table 3: Regional contribution to Spanish contamination: SO_2.

	CAPACITY OF PRODUCTION EFFECT >0 $(P_j-P_j^*)E^k > 0$	CAPACITY OF PRODUCTION EFFECT ≤ 0 $(P_j-P_j^*)E^k \leq 0$
CONTAMINANT INTENSITY EFFECT >0 $(E_j^k-E^k)P_j^* > 0$	Aragón (II)	Asturias(+) (I) Canarias(+) Castilla-La Mancha(+) Galicia(+)
CONTAMINANT INTENSITY EFFECT ≤ 0 $(E_j^k-E^k)P_j^* \leq 0$	Illes Balears(-) (III) Catalunya(-) Madrid(-) Navarra(-) Euskadi(-) La Rioja(-)	Andalucia (IV) Cantabria Castilla y León C. Valenciana Extremadura Murcia Ceuta e Melilla

NOTE: Positive (negative) signs represent regions with total contribution to contamination intensity total superior (inferior) to the mean.

Table 4: Regional contribution to Spanish contamination: Nox.

	CAPACITY OF PRODUCTION EFFECT >0 $(P_j-P_j^*)E^k > 0$	CAPACITY OF PRODUCTION EFFECT ≤ 0 $(P_j-P_j^*)E^k \leq 0$

CONTAMINANT INTENSITY EFFECT >0 $(E_j^k\text{-}E^k)P_j^* > 0$	Aragón Illes Balears	Andalucia(-) Asturias(+) Canarias(+) Castilla-La Mancha(+) Galicia(+) Ceuta e Melilla
CONTAMINANT INTENSITY EFFECT ≤ 0 $(E_j^k\text{-}E^k)P_j^* \leq 0$	Catalunya(-) Madrid(-) Navarra(-) Euskadi(+) La Rioja(-)	Cantabria Castilla y León C. Valenciana Extremadura Murcia

NOTE: Positive (negative) signs represent regions with total contribution to contamination intensity total superior (inferior) to the mean.

Table 5: Regional contribution to Spanish contamination: CO.

	CAPACITY OF PRODUCTION EFFECT >0 $(P_j\text{-}P_j^*)E^k > 0$	CAPACITY OF PRODUCTION EFFECT ≤ 0 $(P_j\text{-}P_j^*)E^k \leq 0$
CONTAMINANT INTENSITY EFFECT >0 $(E_j^k\text{-}E^k)P_j^* > 0$	Navarra Euskadi	Andalucia(-) Asturias(+) Cantabria(+) Castilla-La Mancha(+) Extremadura(-) Galicia(-)
CONTAMINANT INTENSITY EFFECT ≤ 0 $(E_j^k\text{-}E^k)P_j^* \leq 0$	Aragón (+) Illes Balears(+) Catalunya(-) Madrid(-) La Rioja(+)	Canarias Castilla y León C. Valenciana Murcia Ceuta e Melilla

NOTE: Positive (negative) signs represent regions with total contribution to contamination intensity total superior (inferior) to the mean.

Table 6: Regional contribution to Spanish contamination: VOC.

	CAPACITY OF PRODUCTION EFFECT >0 $(P_j\text{-}P_j^*)E^k > 0$	CAPACITY OF PRODUCTION EFFECT ≤ 0 $(P_j\text{-}P_j^*)E^k \leq 0$
CONTAMINANT INTENSITY EFFECT >0 $(E_j^k\text{-}E^k)P_j^* > 0$	Aragón Navarra La Rioja	Andalucia(+) Castilla-La Mancha(+) Castilla y León (+) Extremadura(+) Galicia(-) Murcia(-)
CONTAMINANT INTENSITY EFFECT ≤ 0 $(E_j^k\text{-}E^k)P_j^* \leq 0$	Illes Balears (-) Catalunya (-) Madrid(-) Euskadi(-)	Asturias Canarias Cantabria C. Valenciana Ceuta e Melilla

NOTE: Positive (negative) signs represent regions with total contribution to contamination intensity total superior (inferior) to the mean.

4 CONCLUSIONS

Reducing greenhouse gas emissions has become a main plank of sustainable development at world level. Though, the greenhouse effect global warming will have a long-term damaging impact world-wide on health, animal and plant life, agriculture, and fisheries. Therefore, urgent action is needed as well as a deep study about the origin and level of emissions from a regional perspective.

It has been noted that Spain is an important emission producer among EU countries. Moreover, the pollution behaviour is very different by regions. In fact, Aragón, and Galicia account for the highest total Spanish gas emissions (almost 50% of SO_2), in spite of these high values do not correspond with regional economic development. Thus, Aragón (Galicia) is characterised by having a “total value added per capita” above (below) the Spanish average.

On the other hand, there are several developed regions, such as Madrid, Catalunya, Euskadi, and Navarra, with a net negative contribution to total pollution despite their strong industrial activity.

Previous empirical analysis have shown an unequal pattern by region. It would be convenient to improve the productive structure of less developed regions (with high emissions), encouraging the use of non contaminant technologies. Then, it would be preferable the implementation of different environmental policies by region, in order to reduce the atmospheric pollution problems. In summary, in order to help resolve the problem of atmospheric pollution, it is necessary to step in with a global strategy, taking into account the specific characteristic of the various Spanish regions.

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