Evolution of Greenhouse Effect Gas Emissions in Road Transport sector in Spain in 1990-2009

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Abstract

The investigation we here present comes from the idea that road transport on its different varieties, goods and passengers, and on this last one on its two types, private and public transport comprises a sector with a remarkable socioeconomic relevance. In fact, there are estimations that settle its contribution to Spain´s GDP at an average of 7% and a maximum of 10% if own transport and production of means and infrastructures are included. Therefore, to the obvious benefits that contribute to the economy, which in a great way are reflected on its corresponding statistics, the remarkable costs it involves should be substracted not only in terms of energy dependence increase, but also on the enormous and dramatic cost due to accidentality and the problems caused in terms of contamination, soil use and infrastructure congestion. The methodological bases are settled in it, for the construction, in phases of a system of indicators that would allow evaluation and follow-up of sustainability on the transport sector in its triple dimension: economic, environmental and social; the synchronic and diacronic comparison of the indicators; the establishment of limit and critical values, and desired and goal values on realistic progressions to the desired.

Keywords: Greenhouse effect gas emissions, CO_2, road transport, Spain, Regional differences.

1. Introduction

Transport sector in Spain has an important direct as well as indirect socioeconomic repercussion, over other economic, productive and consumption activities. It is an strategic activity for basic economic sectors as industry, commerce and tourism, that without its participation would not be able to have the necessary raw materials, give exit to the products, or receive its clients. And that is because the energy consumed in private transports represents, in Spain, the 50% of the total consumption in road transport. The remaining percentage basically corresponds to the transport of goods (over 47%), and with a minimum participation, to public transport (3%). Social and economic development has powered a great increase in people´s mobility (the number of kilometres covered per passenger). Since 1985, the consumption in this sector has increased, multiplied by 2.5. Transport needs actions to enable the increase in energy efficiency and significantly soften consumption.

Therefore, nobody questions the socioeconomic relevance of road transport, but nevertheless with an important cost regarding city air pollution (Gurjar *et al.,* 2008, Colvile *et al.*, 2001) and its effect on human health (Curtis *et al.*, 2006). The sector in Spain is not foreign to this situation, and as portrayed in the "Inventario Nacional de Emisiones a la Atmósfera" (MMA, 2010), in 2009 the emissions in road transport caused 26% of particles of an aerodynamic diameter up to 2.5 microns (PM 2,5) and 27% of the CO_2 of the total generated in Spain.

These values confirm the relevance of road transport when it comes to designing policies to conduct in an efficient way, from a cost/benefit analysis point of view, to the decrease in air contaminants nationwide.

2. Objectives and methodology

The objectives of the present project, briefly exposed, are to get to know the inherent reality of greenhouse effect emissions in the road transport sector, in Spain, as well as taking into account the generated territorial differences, focusing on the following aspects:

- Locating, classifying and analysing the available information regarding the Spanish situation.
- Developing and putting into practice new methodologies that would contribute to a better knowledge of the mentioned reality.
- Drawing conclusions from the Spanish situation in the most relevant aspects.

For doing this, we have used a methodology for calculating the weighted reduction coefficients for the corresponding emissions of the greenhouse effect gases, regarding the Autonomous Communities (Autonomous Community (A.C.): geographical and administrative division of the Spanish territory), starting with two inverse logarythmic distribution functions, which take the initial rate of year 1990 as a reference point (focus year, portrayed in the Kyoto Protocol, with the objective to reduce GHG emissions of CO_2, CH_4 and N_2O), for the greenhouse effect emission values in relation to the Gross Domestic Product (GDP) and in relation to the total population of each of the A.C.

Detaching the mathematical formulation of those logarithmic functions, we have designated the corresponding variables with the following values: each Autonomous Community (i), in a year (t), the rate of greenhouse effect gas emissions as tons of equivalent CO_2 (GHG), divided by the Gross Domestic Product of that specific year (t), expressed in millions of Euros (GDP).

$$E(GDP)_{i,t} = \frac{GHG_{i,t}}{GDP_{i,t}} \quad (\text{EQ } CO_2 \text{ t / million €}),$$

In the same way, we have calculated for each A.C. (i), in a year (t), the greenhouse effect gas emissions in tons of equivalent CO_2, divided by the total of population at the beginning of each year, related to the residents (P).

$$E(\ln h.)_{i,t} = \frac{GHG_{i,t}}{P_{i,t}} \quad (\text{EQ } CO_2 \text{ t /resident})$$

Such formulation, taking into consideration the initial rate of road transport emissions per Autonomous Community in Spain, aims to analyse in a concise way the links that exist between contamination and climate change itself; whereas the inverse logarythmic distribution function fits better to the objectives of obtaining the weighted reduction coefficients, relating the highest levels of greenhouse effect emissions decrease in road transport, in those areas where contamination problems are bigger.

In the same way, the methodology of the CORINE-AIRE project, from the technical report of the European Agency for the Environment ("COPERT IV Computer Programme to Calculate Emissions from Road Transport") for calculating the emissions, the emission factors and the CO_2, CH_4 and N_2O emissions, has been the basis. The formula for calculating the final emissions of CO_2 in road transport will stand as follows:

$$E^F_{f,CO_2} = 44{,}011\frac{Q_f}{12{,}011 + 1{,}008r_{H/C} + 16{,}000r_{O/C}}$$

The total calculated values (E^F_{f,CO_2}) are the CO_2 final emissions produced by the fuel consumption f. The total fuel consumption is represented by Q_f, and the other variables that are included in the equation are the relation between the number of hydrogen and carbon atoms in the fuel ($r_{H/C}$) and the relation between the number of oxygen and carbon atoms in the fuel ($r_{O/C}$).

In the same way, in order to achieve the Kyoto Protocol´s objectives for reducing CO_2 emissions in transport by 8% from 2008 to 2012 taking as a reference year 1990 ($GHG_{i,2012}$=c´*$GHG_{i,1990}$; "c´" is the total residual coefficient complementary to the reduction coefficient), there has been taken as a reference the following mathematical base (Tolón, A. et aliis):

$$a = \frac{GHG_{2012}}{\sum_{i=1}^{n}\left(GHG_{i,1990} \Big/ \ln E_{i,1990}\right)} = \frac{c * GHG_{1990}}{\sum_{i=1}^{n}\left(GHG_{i,1990} \Big/ \ln E_{i,1990}\right)}$$

Where an inverse logarythmic distribution function has been used for calculating the residual coefficient (c´) of each Autonomous Community (i), according to its initial rate of emission (E_i), $c'_i = f(E_{i,1990}) = a(\ln E_{i,1990})^{-1}$; where ($a$) is the factor that modulates the weighted coefficient (c'_i), $GHG_{i,2012} = \left(a(\ln E_{i,1990})^{-1}\right) GHG_{i,1990}$; and GHG is the sum of the emission quantities of each of the Autonomous Communities, $GHG_{2012} = \sum_{i=1}^{n} \frac{a * GHG_{i,1990}}{\ln E_{i,1990}}$.

The principal problem of the investigation comes in the need of homogeneize the mathematical formulation to the research data of each of the Autonomous Community, an essential matter as "homogeneity" is the principal requisite for being able to realize inter-regional comparisons (for variables such as the emission of contaminant gases of road transportation, or for the global set of data bases used). The data set and values of the corresponding "Greenhouse Effect Gas Emissions" for the Spanish territorial scope used in the analysis in our study are periodically published by the "Departamento General para la Evaluación de la Calidad Ambiental" –DGECA-, but also, data from the Confederación Sindical de Comisiones Obreras –CCOO- (Nieto and Santamarta, 2008) has been used as well. On the other hand, we have obtained from the "Instituto Nacional de Estadísica" (INE) the ones referring to population and the Gross Domestic Product (GDP), attending to Autonomous Communities. The time analysis carried out, including the Autonomous Cities of Ceuta and Melilla, takes as a reference the 1990-2009 period.

3. Results

Since the application of the exposed methodology, greenhouse effect gas emissions, in general, and those of road transportation, in particular have evolved unevenly and with an increase or reduction of very heterogeneous values in the Spanish regions. On the other hand, it is necessary to emphasize that these progressive increases of Greenhouse Effect Gas emissions, mainly come from road transport, and that they are related to the implantation of different CO_2 emission reduction policies and programs. If we get into the analysis of the results, we see how the increase of the emissions of road transport has been very quick, going from 50,000 thousands tons in the 1990, up to 300,000 thousands tons in year 2009.

If we establish a comparison between the emission of Greenhouse Effect Gases emissions regarding road transport, and the total of GHG (Greenhouse Effect Gas) emissions in Spain, we can observe how a progressive upward trend appears, along the whole research period, going from 280,000 thousands of emitted CO_2 tons in year 1990 up to 370,000 thousands of CO_2 tons of in year 2009.

If we go deep into the analysis of the different Autonomous Spanish Communities, we find that one of the most relevant Communities of the research is the Autonomous Community of Castilla y León that has presented very high levels of emission (third position after Cataluña and Andalucia) but that has been reducing progressively the total of its equivalent CO_2 emissions, from 34,787 thousand tons in 1990 to 31,326 thousand tons in 2009. In the same way, it happens that Asturias has been reducing its total emissions from 27,445 thousands of tons in 1990 to 22,238 thousands of tons in 2009. Whereas the rest of the Autonomous Communities have been increasing progressively their total CO_2 emissions. It is necessary to emphasize as an interesting index the absolute values for the Community of Madrid, since even though, it is a cosmopolitan, very populated capital city and a great economic support in macroeconomic terms with very much movement of vehicles every day, … they are very low as consequence of the fact that the biggest part of its economy relies on the service sector, including tourism sector, and it is less intensive than in past decades, regarding emissions in the secondary or industrial sectors.

As in the case of Madrid, emissions have scarcely increased in 10,000 thousand tons since 1990. Other Autonomous Communities like Islas Baleares, Islas Canarias, Cantabria, Navarra, Murcia and the Autonomous Cities of Ceuta and Melilla, have increased their CO_2 emissions progressively but without surpassing 5,000 thousands of tons.

In the same way, it is necessary to distinguish that in years 2008 and 2009 the total emissions descreased in relation to 2007 in all the Autonomous Communities, with the exception of Islas Canarias, which increased their emissions from 15,847 thousand tons up to 16,511 thousand tons in 2008. Islas Baleares produced 10,614 thousand tons in 2007 and 10,630 thousand tons in 2008. Rioja emitted 3,947 thousand tons in 2007 and 4,423 thousand tons in 2008. In Navarra, the emissions increased from 7,739 thousand tons in 2007 up to 7,963 thousand tons in 2008. The Region of Murcia emitted 11,158 thousands of tons in 2007 and up to 12,458 thousands of tons in 2008, and Comunidad Valenciana 32,568 thousands of tons in 2007 opposite to the 35,606 thousands of tons of 2008, increasing its emissions as a consequence of the increase of tourism and of the increase of the vehicle fleet, though they diminished on the following year.

Table 1.-Evolution of the emissions: absolute Values (Gq equivalent CO_2)

Autonomous Communities	1990	1995	2000	2005	2006	2007	2008	2009
Andalucía	36,749	42,211	29,747	65,812	65,343	67,177	58,251	55,975
Aragón	15,820	17,852	16,957	22,018	21,791	22,637	21,302	18,393
Asturias	27,445	28,601	24,231	33,660	30,462	32,999	25,816	22,238
Baleares	5,729	6,617	7,190	10,155	10,362	10,614	10,630	10,377
Canarias	8,470	8,277	10,235	16,527	15,707	15,847	16,511	14,785
Cantabria	4,377	5,131	4,668	6,972	7,042	7,083	7,170	6,405
Castilla y León	34,787	36,676	35,600	45,609	42,567	43,471	39,659	31,326
Castilla-La Mancha	17,988	17,841	18,714	26,541	27,064	28,347	25,173	23,092
Cataluña	37,453	46,377	46,102	57,729	56,171	57,106	53,688	50,029
Ceuta	286	308	321	388	438	524	533	523
Comunidad Valenciana	17,427	20,936	20,848	32,332	32,150	32,568	35,606	30,187
Extremadura	5,455	5,834	6,106	8,712	9,386	9,537	9,346	8,864
Galicia	27,316	30,928	29,664	35,137	33,846	35,168	29,868	27,795
La Rioja	1,586	1,747	1,806	4,006	4,100	3,947	4,423	3,497
Madrid	15,481	17,851	18,604	27,673	27,532	27,860	26,395	24,687
Melilla	165	215	229	275	305	331	345	332
Navarra	4,306	4,801	4,905	7,980	7,768	7,739	7,963	7,383
País Vasco	16,556	16,901	15,719	24,238	23,965	23,017	22,634	21,607
Región de Murcia	5,775	5,736	5,837	8,083	10,024	11,158	12,458	10,153
Total Spain	283,171	314,840	297,483	433,847	426,023	437,130	407,771	367,648

Source: own elaboration, through the works of Rodrigo, F and Santamarta, J.

Unlike the rest of the sectors (table 2), transport, and more precisely road transport, (which still presents the major weight of the total of GHG emissions in Spain) has increased its emissions in a constant and progressive way from 1990 to year 2009, going from 61,575.8 thousand tons in year 1990 to 294,118.4 thousand tons in year 2009. It is necessary to emphasize that in years 2008 and 2009 the economic crisis has promoted a decrease in the registrations of new vehicles, if we take as a reference the percentage trend of previous years. But they continued in an upward trend in spite of the reduction of wages, of subsidies and the increase of unemployment, among other factors, which has substantially reduced the purchasing power of individuals, reverberating in the consumption of these but surprisingly not producing a decrease in the use of private vehicles. Therefore the emissions, far from diminishing, like in the rest of the sectors, they have increased.

It is fundamental to emphasize that this fact has not happened in all of the Autonomous Communities. Cataluña emitted 40,023.2 thousand tons in 2009, Castilla y León presented one of the major emission increases of the whole Spain going from 7,704.6 thousand tons in 1990 up to 25,060.8 thousand tons in 2009, and Comunidad Valenciana emitted 24,1496 thousand tons in 2009. These three Communities are those that more CO_2 emitted in year 2009 and that also experimented the biggest increases.

On the other hand, together with the autonomous cities of Ceuta (418.4 thousand tons) and Melilla (265.6 thousand tons), the Autonomous Communities of Cantabria (5,124 thousand tons in 2009, 4,060 thousand tons more than in 1990) and Navarra (5,906.4 thousand tons in 2009 compared to the 1040.4 thousand tons of 1990), increased their emissions but in small amounts (less than 1,000 tons between 1990 and 2009) in comparison to Madrid that emitted 19749.6 thousand tons in 2009 in comparison to the 4239.8 thousand tons in 1990, Galicia which is one of the Communities which increased its emissions the most during the last decades going from 6,419.2 thousand tons in 1990 to 22,236 thousand tons in 2009 along with Aragón which emitted 3370.6 thousand tons in 1990 and 14714.4 thousand tons in 2009, Asturias which is one of the most representative Communities regarding road transport emissions referred to the total population and economic importance regarding the total GDP of Spain (emitted 5,370.4 thousand tons in 1990 and 17,790.4 thousand tons in 2009) or País Vasco which augmented its emissions in 13,836.8 thousand tons between 1990 and 2009.

Table 2.- Evolution of road transport emissions: Absolute values (Equivalent Gq CO_2)

Autonomous Communities	1990	1995	2000	2005	2006	2007	2008	2009
Andalucía	9,463.20	11,283.14	12,657.36	32,247.88	36,592.08	40,306.20	40,775.70	44,780.00
Aragón	3,370.60	3,969.46	4,860.72	10,788.82	12,202.96	13,582.20	14,911.40	14,714.40
Asturias	5,370.40	7,087.30	8,010.00	16,493.40	17,058.72	19,799.40	18,071.20	17,790.40
Baleares	1,552.20	1,864.06	2,088.00	4,975.95	5,802.72	6,368.40	7,441.00	8,301.60
Canarias	2,170.40	2,885.96	3,234.24	8,098.23	8,795.92	9,508.20	11,557.70	11,828.00
Cantabria	1,063.40	1,171.06	1,323.12	3,416.28	3,943.52	4,249.80	5,019.00	5,124.00
Castilla y León	7,704.60	8,968.52	10,027.20	22,348.41	23,837.52	26,082.60	27,761.30	25,060.80
Castilla-La Mancha	4,117.80	5,034.92	5,712.72	13,005.09	15,155.84	17,008.20	17,621.10	18,473.60
Cataluña	3,545.80	11,097.02	12,596.16	28,287.21	31,455.76	34,263.60	37,581.60	40,023.20
Ceuta	62.60	80.30	82.56	190.12	245.28	314.40	373.10	418.40
Comunidad Valenciana	4,946.40	6,012.82	6,648.96	15,842.68	18,004.00	19,540.80	24,924.20	24,149.60
Extremadura	1,315.40	1,516.02	1,832.16	4,268.88	5,256.16	5,722.20	6,542.20	7,091.20
Galicia	6,419.20	7,183.66	8,063.76	17,217.13	18,953.76	21,100.80	20,907.60	22,236.00
La Rioja	409.20	474.10	538.80	1,962.94	2,296.00	2,368.20	3,096.10	2,797.60
Madrid	4,239.80	4,954.40	560.40	13,559.77	15,417.92	16,716.00	18,476.50	19,749.60
Melilla	41.00	50.38	57.12	134.75	170.80	198.60	241.50	265.60
Navarra	1,040.40	1,222.10	1,391.28	3,910.20	4,350.08	4,643.40	5,574.10	5,906.40
País Vasco	3,448.80	4,146.56	4,636.08	11,876.62	13,420.40	13,810.20	15,843.80	17,285.60
Región de Murcia	1,294.60	1,571.24	1,782.72	3,960.67	5,613.44	6,694.80	8,720.60	8,122.40
Total Spain	61,575.80	80,573.02	86,103.36	212,585.00	238,572.90	262,278.00	285,439.70	294,118.40

Source: Own elaboration, attending to the percentage values of the Spanish Ministry for Environment, Marine and Rural Affairs (2010).

It is very significant that in the particular case of Asturias (which has passed from 59% to 78% of the total emissions of road transport referred to the GDP, of the total of emissions) and Castilla la Mancha, the two communities which have increased their GHG emissions the most, almost 30% in the last decade. In the case of Murcia, Navarra, La Rioja, Galicia, Extremadura, Baleares and Aragón they show increases of approximately 20% in their CO_2 emissions. And it catches our attention the particular cases of Madrid and Cataluña which have barely increased their emissions in 7% during the last ten years, even though the vehicle fleet has grown more in proportion than if we take as a base the Gross Domestic Product.

We can say, regarding the relation between GHG emissions and population, that in some Autonomous Communities, at a national or regional level, the existing relation between the total of emissions is in inverse proportion to the total of the population living in a certain Community (the percentages of each of the Communities have been found regarding to the total in Spain), despite the implementation of new comprehensive plans and projects to reduce these CO_2 emissions in urban areas, not only in Spain but throughout the European Union, based primarily on the use of public transport, public awareness campaigns of the impact private transport has on the environment, flexibilitation of work schedules to reduce the number of unnecessary trips, and the creation of new and better infrastructure.

4. Conclusions

Greenhouse effect gas emissions from road transport have undergone a constant increase along the last decades, becoming one of the factors with a higher relative weight in the whole set of GHG emissions in Spain. Nevertheless, the whole set of CO_2 emissions experimented a light decrease during the last two years of the research period. We find the direct cause on the economic crisis that our country is going through along with a "significant change in the cultural pattern", which has favoured the reduction of emissions in relatively small but significant percentages.

But above all, we cannot forget that regarding the greenhouse effect gases, CO_2 emissions tripled the recommended values of Kyoto Protocol.

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