Regional patterns of transport and total CO_2 emissions in the EU15 countries

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Abstract

Decarbonisation of the economy is a well-established international trend in environmental research. It is normally defined as a decreasing carbon intensity of the economy, measured by dividing the carbon dioxide (CO_2) emissions with the gross domestic product (GDP). The paper compares two aspects of the carbon intensity: (1) The total CO_2 emission intensity of the economy and (2) the transport CO_2 emission intensity of the economy. Data is gathered from the fifteen European Union (EU15) countries from 1960 to 1999. The countries are grouped by cluster analysis and regional patterns of the groupings are analysed. It can be concluded that while the total CO_2 intensity of the economy has decreased, the transport CO_2 intensity has in fact increased in the EU15 countries. Regarding the whole period, only Ireland and Austria showed decreasing transport CO_2 intensity. It seems, that in the 1990's a change in the trend was achieved also in Denmark, Finland, Sweden and United Kingdom. To analyse the regional dimension of the developments, cluster analysis was performed resulting in four clusters: Southern cluster (Italy, Spain, Portugal, Greece), Mountains of hydro- and nuclear power (Austria, France, Sweden), Northern 1990'ers (Denmark, Finland and Netherlands) and Atlantic fossil cluster (Belgium, Ireland, Germany and UK). Luxembourg turned out to be an outlier.

Key words: carbon dioxide emissions, transport, carbon intensity, european union, cluster analysis

Introduction

The decarbonisation of the economy is a well-established international trend in environmental research. Decarbonisation is normally defined as a decreasing carbon intensity of the economy, measured by dividing the carbon dioxide (CO_2) emissions with the gross domestic product (GDP). The paper compares two aspects of the carbon intensity of the economy: (1) The total CO_2 emission intensity of the economy and (2) the transport CO_2 emission intensity of the economy. Data are gathered from the current fifteen European Union (EU15) countries from 1960 to 1999 and regional patterns are analysed.

There is a clear difference in the trends of the total carbon intensity and transport carbon intensity. Although the total CO_2 emissions have increased, the total carbon intensity has steadily decreased in the World, as well as in the EU15 countries after the first oil crise in 1973. There has been dematerialisation (decarbonisation) in the energy sector, measured as t of CO_2 / total primary energy supply (TPES) and also immaterialisation of the whole economy, measured as TPES/GDP. The growth of GDP however has been so rapid that the positive development has not resulted in reduction of total CO_2 emissions (Kaivo-oja & Luukkanen 2002; 2003.)

Less success has been accomplished in the transport sector. According to Stead (2001) there was no decarbonisation in the EU15 countries in 1970-1995. The technical improvement of the fuel economy was traded off by increased size of vehicles, decreasing number of passengers per vehicle, higher motor power and possibly also ecologically less sound driving habits. In freight transport demands for just-in-time (JIT) deliveries have increased the use of road and air freight, especially vans. Thus indicators of CO_2 emissions/tkm (tonne km) and CO_2 emissions/pkm (passenger km) showed negligible reduction. (Acutt & Dodgson 1998, 28-29; Banister et al 2000; Van den Brink & Van Wee 2001; Stead 2001; Tapio 2002.)

The same can be said about immaterialisation, measured as transport volumes per GDP. Looking at the period of 1970-2000 no decoupling of transport growth from the growth of the economy can be discerned in the EU15 (Peake 1994; Stead 2001; Tapio 2002.)

There is room for some speculation regarding the positive development achieved in some countries in the late 1990's (Tapio 2003b).

There seems to be rather few scholars focusing of the differences and similarities in the general energy and total carbon intensity and the more specific transport intensity and transport CO_2 intensity (see Danielis 1995). Two analyses are of special importance here. The first was carried out by Peake (1994) and the second by Stead (2001). Peake's basic message was, that immaterialisation had occurred in the energy sector (TPES/GDP) but had not happened in transport (freight/GDP nor passenger km /GDP). His data covered the period of 1952-1992 in the UK. Stead made an analysis of transport intensity and tranport CO_2 intensity based on Eurostat statistics for all EU15 countries covering the period of 1970-1995. He showed that the transport intensity and transport energy intensity of the economy showed no reduction.

Our analysis in this paper follows somewhat the line of Peake's and Stead's work. Some special features should however be mentioned: We have a further time frame than them, covering the period from 1960-1999. We analyse the regional patterns of the different countries using cluster analysis. We use CO_2 emissions instead of energy consumption. Stead did not analyse total energy intensities and Peake focused on UK data solely. Our analysis is more limited in terms of transport volumes. Stead defined economic efficiency of transport as GDP/transport energy consumption whereas we consider it more logical to use Peake's definition of having the environmental variables as nominators, *i.e.* t of CO_2/GDP.

Methodological approach

The regional patterns of the carbon intensity of the economy were analysed by grouping the EU15 countries by cluster analysis available in the SPSS 10.1 software. Two time-series of variables were used: the total CO_2 intensity of the economy and transport CO_2 intensity of the economy, covering the period from 1960 to 1999 (IEA 2002). The total number of variables of the cases to be clustered was thus 80. The volume of the economy was measured with the gross domestic product in real terms using purchase power parities (GDP_{ppp}).

As the units of the intensities are similar to each other (t of CO_2 / $US\$_{1995}$) the numerical values of total carbon intensity are naturally larger than transport CO_2 intensity. Without weighting the variables the clustering would be based strongly on total carbon intensity and transport CO_2 intensity would only play a minor role. This effect was ameliorated by multiplying the values of transport CO_2 intensity by 3.797, because transport contributed 26,2% of the total carbon intensity in 1999 and 3.797*26,2%=100%.

The scientific literature of classification shows no signs of consensus when deciding the clustering algorithm (Milligan 1998). In this study the furthest neighbour (complete linkage) method was used to group the countries. The normal euclidean distance (dissimilarity measure) was used as all the variables were on relative scale. As a sensitivity analysis, the Ward method was also tried. The Ward method requires squared euclidean distance.

Hierarchical cluster analysis does not ultimately decide the number of clusters. It only proceeds grouping as long as all the cases are in one group. It is important to decide the number of clusters when they are used further in for example scenario work or tested using external data (see Tapio 2003a; Varho & Tapio 2003). When analysing the regional patterns it seems more relevant to look at the whole clustering procedure and not concentrate on deciding the number of groups. Two outputs of furthest neighbour clustering are especially useful in this regard: the vertical 'icicle' which reveals the exact order of grouping (Table 1) and the dendrogram showing a tree-shape hierarchy (Figure 1). With regard to the Ward method grouping, only the icicle is used as the dendrogram tends to discern only rather large groups (Table 2).

Results

We begin the presentation of the results showing the whole process of clustering. The dendrogram output from the basic furthest neighbour run will be the basis of the analysis (Figure 1). Then we look at the differences and similarities of the icicles produced by the furthest neighbour and the Ward method. Finally, we show the total carbon intesity and transport CO_2 intensity of each cluster disaggregated by country.

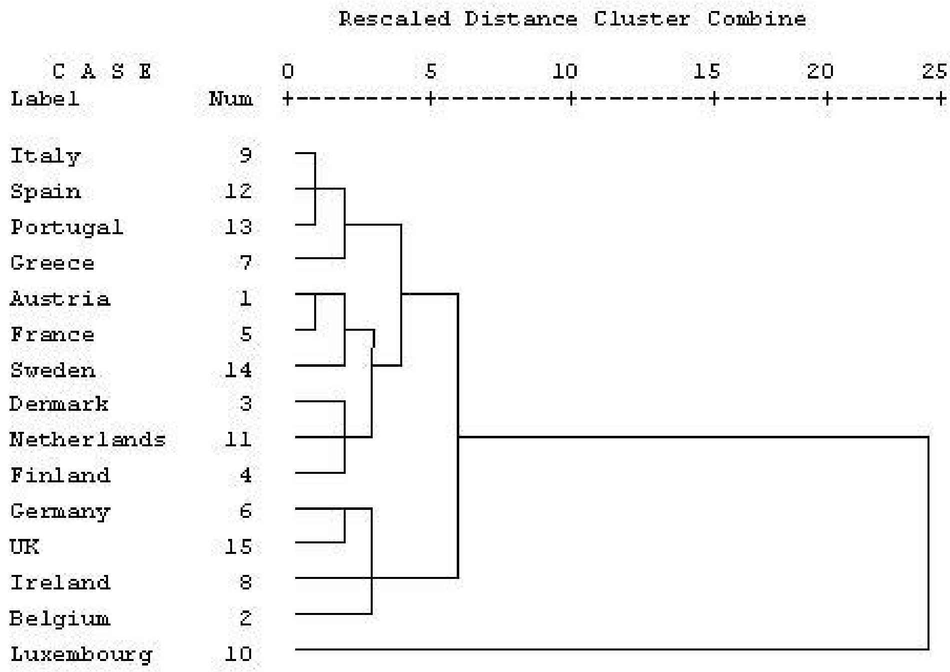

Figure 1: The dendrogram of the grouping of the EU15 countries in terms of total carbon intensity and transport CO_2 intensity using the furthest neighbour method in cluster analysis

The dendrogram can be read from left to right, that is in the beginning all countries are separate cases. The earlier the cases are clustered together the greater the similarity calculated by cluster analysis. For example it can be seen that Germany and UK are closer to each other than Ireland and Belgium, which are grouped to the same cluster later. Finally all cases are included in one cluster.

Table 1: The vertical icicle of the grouping of the EU15 countries in terms of total carbon intensity and transport CO_2 intensity using the furthest neighbour method in cluster analysis

	Case																												
Number of clusters	LUX		IRL		UK		GER		BEL		POR		ESP		ITA		GRE		FIN		NED		DEN		SWE		FRA		AUT
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
5	X		X	X	X	X	X		X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
6	X		X		X	X	X		X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
7	X		X		X	X	X		X		X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
8	X		X		X		X		X		X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
9	X		X		X		X		X		X	X	X	X	X	X	X		X		X	X	X		X	X	X	X	X
10	X		X		X		X		X		X	X	X	X	X	X	X		X		X	X	X		X		X	X	X
11	X		X		X		X		X		X	X	X	X	X	X	X		X		X		X		X		X	X	X
12	X		X		X		X		X		X	X	X	X	X		X		X		X		X		X		X	X	X
13	X		X		X		X		X		X	X	X	X	X		X		X		X		X		X		X		X
14	X		X		X		X		X		X		X	X	X		X		X		X		X		X		X		X

Table 2: The vertical icicle of the grouping of the EU15 countries in terms of total carbon intensity and transport CO_2 intensity using the Ward method in cluster analysis

Case

Number of clusters	LUX		IRL		UK		GER		BEL		POR		ESP		ITA		GRE		FIN		NED		DEN		SWE		FRA		AUT
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
5	X		X		X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
6	X		X		X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
7	X		X		X	X	X		X		X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
8	X		X		X		X		X		X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
9	X		X		X		X		X		X	X	X	X	X	X	X		X		X	X	X		X	X	X	X	X
10	X		X		X		X		X		X	X	X	X	X	X	X		X		X	X	X		X		X	X	X
11	X		X		X		X		X		X	X	X	X	X	X	X		X		X		X		X		X	X	X
12	X		X		X		X		X		X	X	X	X	X		X		X		X		X		X		X	X	X
13	X		X		X		X		X		X	X	X	X	X		X		X		X		X		X		X		X
14	X		X		X		X		X		X		X	X	X		X		X		X		X		X		X		X

The vertical icicles (Table 1 and 2) tell the same story revealing the exact order of the grouping. For example one cannot see in the dendrogram whether Germany, UK, Ireland and Belgium were grouped together before or after the cluster of Austria, France and Sweden was grouped with the cluster of Denmark, Netherlands and Finland. Each country is expressed as a vertical series of crosses (the long ice pins) in the icicle. The mediate columns tell the phase when the cases were grouped together. It is most illustrative to read the icicles bottom-up. The closest cases were thus Spain and Italy (line 14). Then Portugal was grouped together with these two (line 13). The next closest were France and Austria (line 12) and so forth. This illustrative idea is not exactly correct because furthest neighbour method starts by placing the furthest cases into separate clusters, not the closest together.

Southern cluster

The clearest conclusion is that there is a Southern cluster of Italy, Spain, Portugal and Greece. For long time they had a lower total carbon intensity than EU15 countries on average. As the total of EU15 has come down, they have reached the average in the 1990’s. Some variation in this cluster can be detected as the total carbon intensity began to decrease in the early 1970’s in Italy and early 1980’s in Spain whereas Portugal and Greece still continued the carbon intensification of their economy in the 1990’s. Transport CO_2 intensity increased in all of the countries within the whole period of 1960-1999. (Figure 2.)

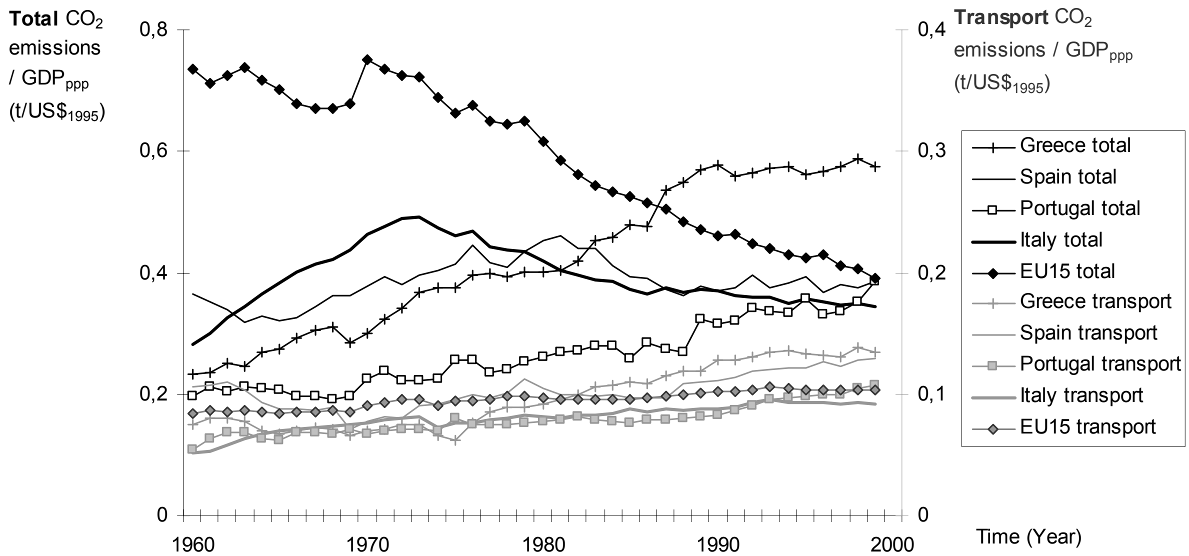

Figure 2: Total carbon intensity (black lines) and transport CO_2 intensity (grey lines) of the economy in the Southern cluster compared to the EU15 average in 1960-1999

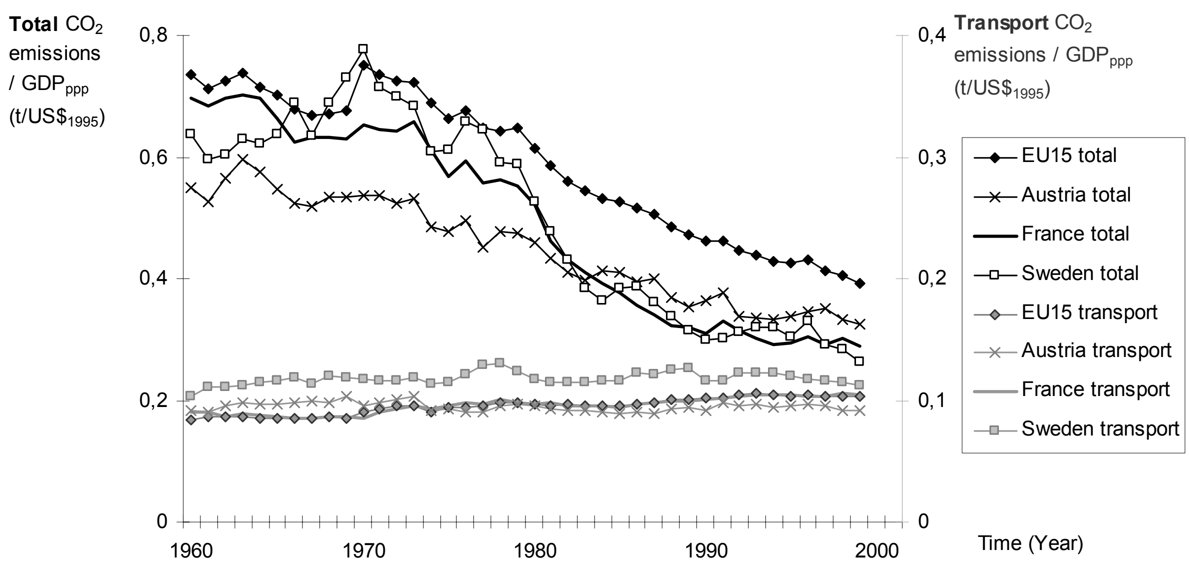

Figure 3: Total carbon intensity (black lines) and transport CO_2 intensity (grey lines) of the economy in the 'good practise energy policy' cluster compared to the EU15 average in 1960-1999

Mountains of hydropower and nuclear energy

Also Austria, France and Sweden are similar to each other as they have reflected the EU15 average development (Figure 3). There seems to be no unifying reason, at least not in terms of a regional pattern. Sweden and France have a low fossil fuel dependency in electricity production: France has relied heavily on nuclear power whereas Sweden and Austria on both nuclear- and hydropower. As for transport CO_2 emissions, France and Sweden have an important domestic car manufacturing industry which explains partly the surprising Swedish decoupling from the other Nordic countries (see also Tengström 1999).

Northern 1990'ers

Denmark, Netherlands and Finland form an understandable cluster as they can all be considered northern proponents of sustainable transport policy (Tengström 1999; Tapio 2003b). Car use has been restricted whereas soft modes and public transport have gained rather large market shares. Regionally they are rather close to each other but mentally even more as the welfare state has been of high status. In energy policy they have not shown such a success, except in the late 1990's.

Atlantic fossil cluster

According to furthest neighbour clustering the above two clusters were more close to each other than the next cluster, comprising of Germany, Ireland, United Kingdom (UK) and Belgium. The Ward method in turn grouped Germany, UK and Belgium together before the previous two clusters. Leaving aside the discussion of the 'true' number of clusters, these countries have a regional Atlantic dimension. Germany and UK have a strong domestic coal resource with strong economic and social interests attached to coal use which explains high total carbon intensity of the economy. Belgium has had a strong metal industry. Ireland seems to be different as it has industrialised during the period and was earlier dependent on oil and coal. Although the success in reducing the total carbon intensity has been remarkable, these countries have remained higher than the EU15 average. The Atlantic fossil cluster has followed the average

EU15 pace in reducing the transport CO_2 intensity of the economy. An important exception is UK showing significant reduction in the 1990's. This is at least partly a result of conscious transport policy decisions (Peake 1994; Banister 1997; Goodwin 1999; Figure 5).

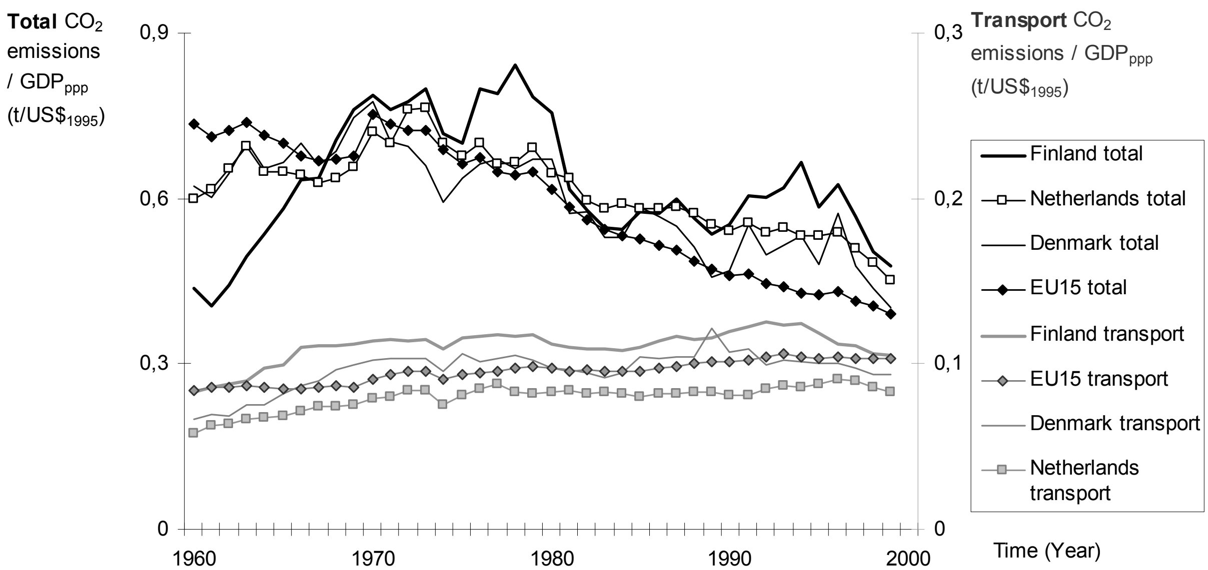

Figure 4: Total carbon intensity (black lines) and transport CO_2 intensity (grey lines) of the economy in the 'Northern 1990ers' cluster compared to the EU15 average in 1960-1999

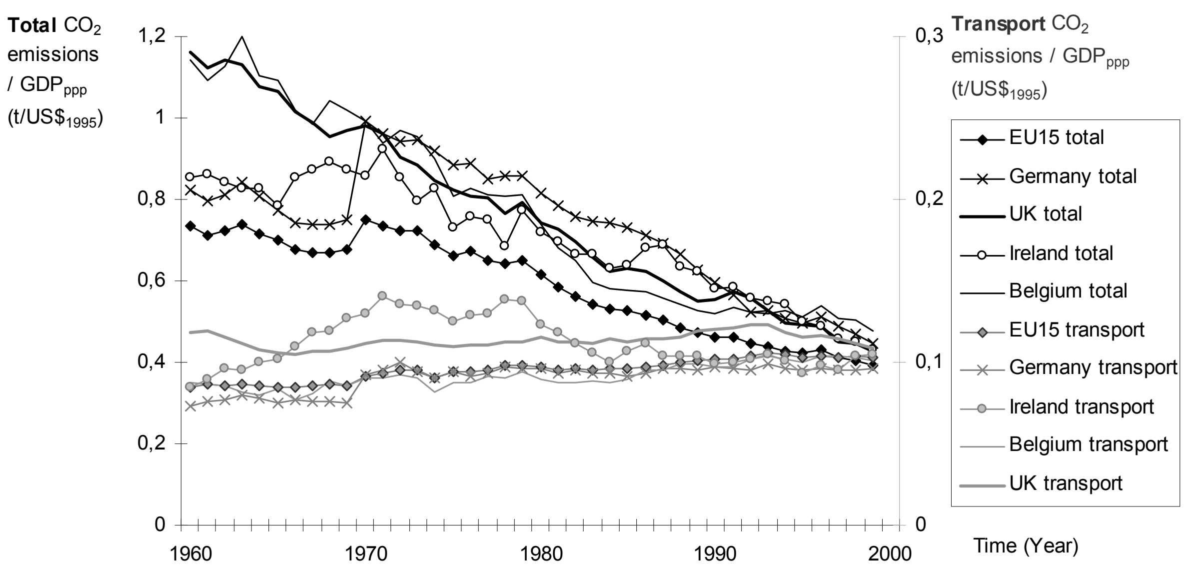

Figure 5: Total carbon intensity (black lines) and transport CO_2 intensity (grey lines) of the economy in the 'Atlantic fossil' cluster compared to the EU15 average in 1960-1999 (German data before 1970 does not include East Germany)

Outlier Luxembourg

Finally, Luxembourg is a clear outlier showing a dramatic reduction from very high total carbon intensity to the level of EU15 average (Figure 6). This extraordinary decrease can be mostly explained by changes in steel industry. On the other hand, transport CO_2 intensity has grown rapidly as Luxembourg has a central geographic position. The transport CO_2 figures of Luxembourg statistics should be considered cautiously as people from neighbour countries come to fill their tanks with the rather cheap gasoline in Luxembourg. And of course, there is a little country effect, in which changes in one powerplant show changes in the whole country.

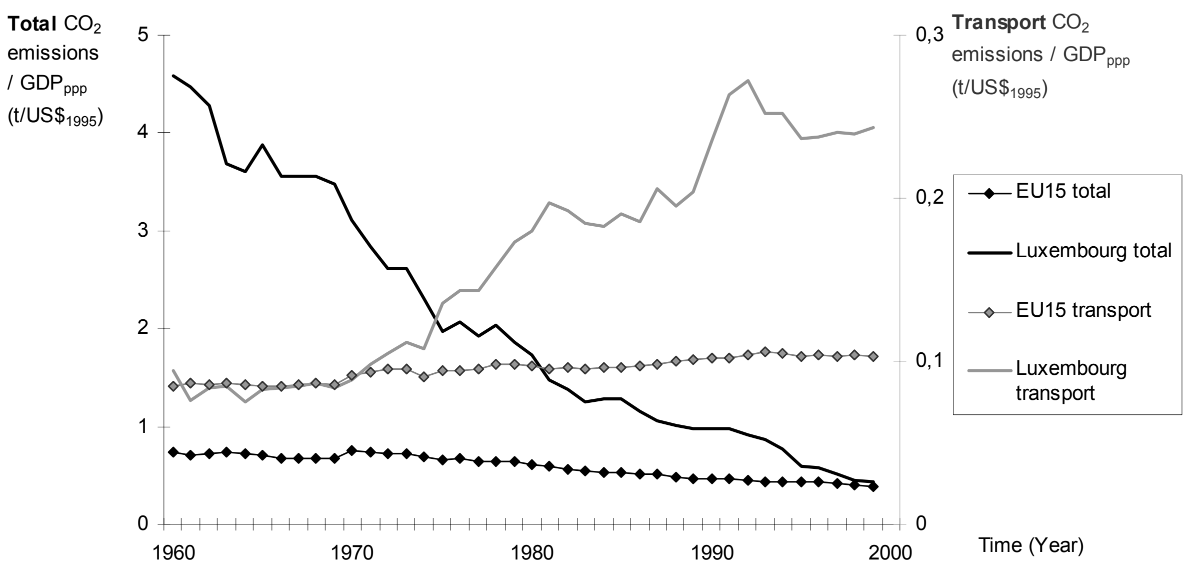

Figure 6: Total carbon intensity (black lines) and transport CO_2 intensity (grey lines) of the economy in Luxembourg compared to the EU15 average in 1960-1999

Discussion

There have been issue specific patterns and regional patterns in the development of total carbon intensity and transport carbon intensity of the economy in the EU15 countries during the last four decades. The major issue specific pattern is that although the total carbon intensity of the economies of the EU15 countries has decreased steadily, transport CO_2 intensity has in fact increased.

Looking at the whole period of 1960-1999, only Ireland and Austria can boast decreasing transport CO_2 intensity. A positive change in the trend was accomplished in some EU15 countries in the 1990's: Denmark, Finland, Netherlands, Sweden and UK. Also it seems that the long period of steady growth in Italy might have stopped.

Regionally it seems that the economic rise of the Southern cluster has been accomplished without due emphasis of climate policy. Higher economic growth rate than the rest of the EU has been a desirable goal of regional policy within the EU. Have the increasing transport volumes and increasing CO_2 emissions of transport only been a natural and therefore acceptable side-effect of the growth? The answer is no, as the CO_2 emissions reported in this paper are divided by GDP and therefore the GDP effect is eliminated. Now that the EU is enlarging it is important to learn from the past: structural funding to the accession countries should be strongly focused on rail and public transport projects instead of motorways. Of course the cultural new freedom to use private cars is a strong trend, but this should not be fuelled with investments.

The fossil fuel dependence of the Atlantic cluster is still quite high despite all the efforts to decrease the carbon intensity. The burden is especially strong in Germany and UK having strong domestic interests to the use of coal.

The northern 1990'ers have done some improvement during the last decade according to IEA statistics but is the improvement true and is it enough? International flights are not included in the IEA statistics, this bias obviously affects the trends.

The most surprising regional pattern was to have Austria, France and Sweden in the same cluster. This grouping seems to lack a suitable interpretation.

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Appendix A: Growth rates by decade

The paper provides a detailed analysis only on carbon intensities which does not tell anything of the pace of growth. This appendix includes also the growth or reduction rates of CO_2 emissions and GDP_{ppp}.

Table 3: The percentual change of GDP_{ppp}, total CO_2 emissions and transport CO_2 emissions[a] by decade in the EU15 countries in 1960-1999 (IEA 2002)

Decade	**1960-1970**			**1970-1980**			**1980-1990**			**1990-1999**		
Country	GDP	Total CO_2	Transp CO_2	GDP	Total CO_2	Transp CO_2	GDP	Total CO_2	Transp CO_2	GDP	Total CO_2	Transp CO_2
Austria	58	55	66	43	22	42	26	0	21	21	9	22
Belgium	61	40	67	39	3	37	22	-14	34	19	9	23
Denmark	55	93	137	21	5	16	17	-19	28	22	5	7
Finland	58	183	114	43	37	40	36	-1	45	17	1	4
France	72	61	64	38	11	57	28	-24	31	15	8	20
Germany[b]	54	86	96	31	7	36	24	-9	26	15	-14	14
Greece	131	198	114	57	109	107	7	54	49	20	19	26
Ireland	51	51	130	59	33	51	43	16	15	78	32	87
Italy	73	184	156	43	30	53	25	10	36	14	6	18
Luxembourg	41	-4	33	29	-28	161	55	-12	103	62	-29	68
Netherlands	64	97	123	33	19	39	24	4	23	27	7	30
Portugal	85	113	133	59	85	83	37	65	45	25	52	63
Spain	104	111	50	43	71	93	33	9	40	23	29	45
Sweden	57	92	79	21	-18	20	22	-31	22	15	1	11
UK	32	11	25	21	-8	25	30	-2	37	21	-7	9
EU 15	**60**	**64**	**73**	**35**	**10**	**44**	**26**	**-5**	**32**	**18**	**0**	**20**
USA	46	50	56	38	10	19	37	3	15	32	14	19
Japan	170	184	159	54	21	63	48	17	28	12	11	26

[a] Transport CO_2 emissions do not include international aviation and maritime bunkers.

[b] The German data for 1960 does not include East Germany