Coefficients for Carbon Dioxide Emissions from Mobile Sources in the U.S., Canada, and the U.K. Derived from a Simple Spreadsheet

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A simple spreadsheet was devised to link carbon dioxide emissions from the three fossil fuels and three emission sectors.[1] All emissions from the fossil fuels are assumed to originate from oil, natural gas or coal which may be thought of as arising from the three states of matter in the form of liquid, gas, or solid carbon-bearing inputs. The carbon dioxide emissions are considered as released to the atmosphere from only three sectors—electrical generation, mobile sources, and all other stationary sources. By linking the physical form of carbon-bearing fuels to these three distinctly different applications, a spreadsheet of this kind reflects the deep structural divisions in the energy economy directly. To take one example of these different circumstances, carbon dioxide released in the generation of electricity is a candidate for capture for subsequent sequestration although emissions from Mobile Sources in the transportation sector or from the more dispersed catch-all category Other Stationary Sources are unlikely to be. Nothing in principle, however, prevents the further division of this latter category into a separate column distinguishing the emissions of a specific group of energy-intensive industries with substantial emissions, such as steel and cement, if the data available warrant.

The coefficients derived from the spreadsheet should reflect the structure of the energy economy and thus share the characteristics of those derived from economic input-output tables in that they should change only slowly with time. A previous application of this style of spreadsheet dealt with world emissions and the transfer of embodied energy among nations.[2]

This note focuses on two coefficients derived from the consumption of oil in the transportation sector of the U.S., Canada, and the U.K. because of the importance of these emissions in planning measures to deal with carbon dioxide mitigation. In previous papers, it was shown that if more of the oil produced could be dedicated to this sector, the effect of the timing of the peak of world conventional oil production might be delayed for about a decade.[3,4]

United States:

The data was obtained from Chapter 2 of a yearly report titled *Carbon Dioxide Emissions* taken from *Emissions of Greenhouse Gas in the United States in 2000*, published by the Energy Information Administration of the U.S. Department of Energy.[5] The data from this source, expressed in million metric tonnes of carbon and covering the period from 1990 to 2000 (preliminary for the latter year), could be used directly although a small correction was needed to account for certain minor adjustments listed in the publication. This change was applied in proportion to the total emissions from the three fossil fuels and was not significant.

A spreadsheet was prepared for each of the eleven years from 1990 to 2000 inclusive. The spreadsheet for 2000 follows as an example with carbon dioxide expressed in gigatonnes carbon (GT C).

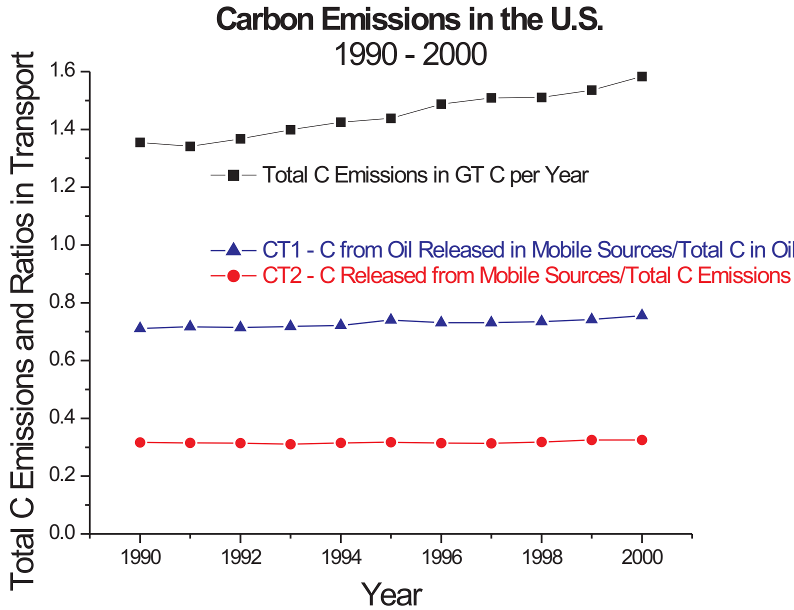
Carbon Emissions in U.S.A. in 2000

Fuel	Electrical Gener.	Mobile Sources	Other Stationary Sources	Total GT C
Oil	0.026	0.504	0.138	0.668
Nat.Gas	0.093	0.011	0.231	0.335
Coal	0.522	-	0.058	0.580
Total	0.641	0.515	0.427	1.583

Derived Transportation Coefficients:

$$C_{T1} = 0.504/0.688 = 0.755$$
$$C_{T2} = 0.515/1.583 = 0.325$$

Two coefficients were chosen to follow the carbon entering with oil in the transportation sector. Coefficient C_{T1} is the ratio between the carbon released



from mobile sources to the total carbon supplied in oil and Coefficient C_{T2}, is the ratio of the carbon released from all fuels consumed in mobile applications to the total overall carbon released from the three fossil fuels together. These two coefficients appear in the graph for the U.S. over the eleven-year period for which data is available.

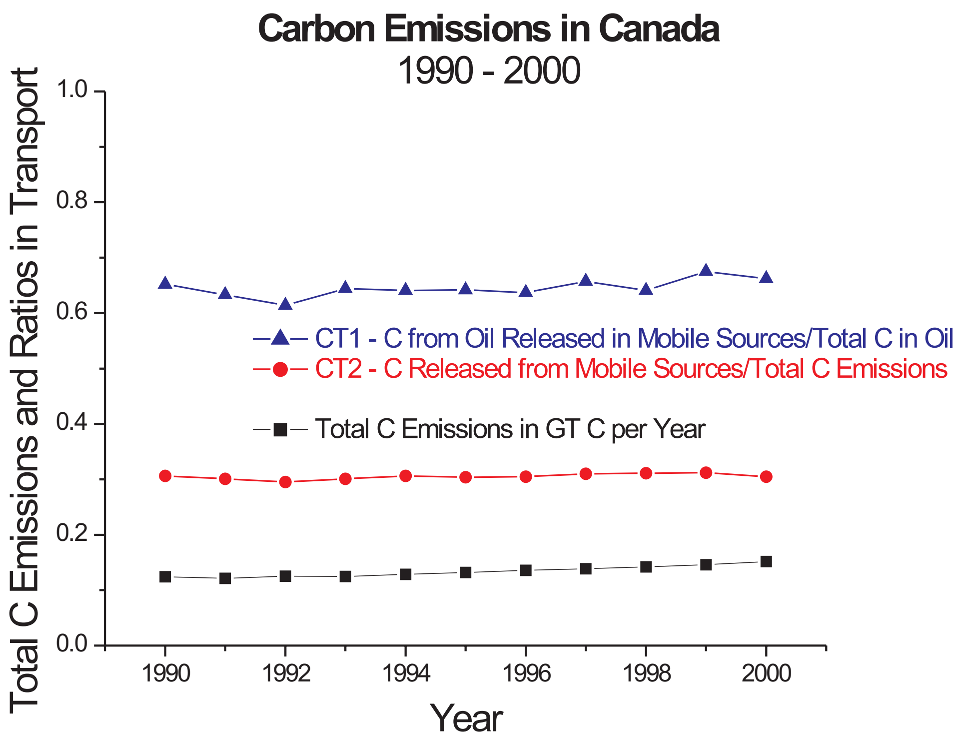
The value for Coefficient C_{T2} is essentially constant over these years with the average value of 0.317 with a Standard Deviation of 0.004. Coefficient C_{T1} does, however, show a slowly rising trend with an average value of 0.729 and a Standard Deviation of 0.013. The total carbon emissions rise steadily during these years as shown on the plot.

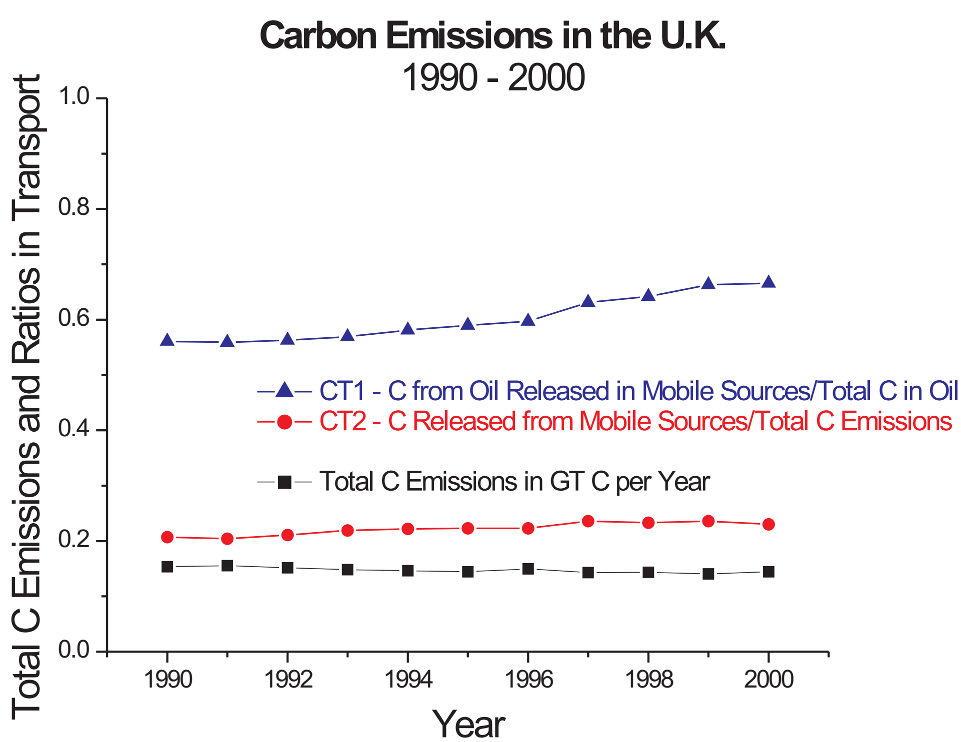
Canada:

Data for Canada was taken from *Canada's Greenhouse Gas Inventory 1990-2000* published by Environment Canada and dated June 2002.[6] This information is not sufficient to construct the full spreadsheet because of the absence of data on the emissions from power generation by fuel type. The two oil transport coefficients may, however, be estimated from the Appendix titled *Greenhouse Gas Emissions Summary for Canada* given certain assumptions. The emissions from mobile sources in the transportation sector may be read directly by year from this Appendix though a small error is introduced because some natural gas consumed in vehicles was included in this figure. Total carbon dioxide emissions were taken as the sum of the emissions from `Fuel Combustion' plus those from `Industrial Processes.' The emissions classed as `Fugitive Sources', `Agriculture,' and `Land Use and Forestry' were not included in the total to be consistent with the carbon balance at the heart of the spreadsheet in that the carbon dioxide emissions were assumed to arise only from the combustion of the fossil fuels.

The contribution from the consumption of oil presented a special difficulty due to the absence of information on fuel sources. In this situation, the emissions from oil were estimated by multiplying the total emissions calculated as above by the percent contribution arising from the consumption of oil for each year derived from the *Carbon Dioxide Factsheet* published yearly by this author.[7] With these assumptions, it was possible to calculate the two ratios for the eleven-year period 1990-2000.

These ratios appear plotted in the figure for Canada along with the total emissions of carbon dioxide over this period. The average value of C_{T1} for Canada was 0.645 with a Standard Deviation of 0.015 and the average value of C_{T2} was 0.305 with a Standard Deviation of 0.005. C_{T1} fluctuated somewhat erratically with a slight tendency to increase over the years which suggests more of the oil consumed was being directed to the transportation sector. The value of C_{T2} was stable. There was a slow increase in the total emissions of carbon dioxide.


Carbon Emissions in Canada
1990 - 2000
Total C Emissions and Ratios in Transport
1.0
0.8
0.6
0.4
0.2
0.0
1990
1992
1994
1996
1998
2000
Year
CT1 - C from Oil Released in Mobile Sources/Total C in Oil
CT2 - C Released from Mobile Sources/Total C Emissions
Total C Emissions in GT C per Year


Carbon Emissions in the U.K.
1990 - 2000
Total C Emissions and Ratios in Transport
1.0
0.8
0.6
0.4
0.2
0.0
1990
1992
1994
1996
1998
2000
Year
CT1 - C from Oil Released in Mobile Sources/Total C in Oil
CT2 - C Released from Mobile Sources/Total C Emissions
Total C Emissions in GT C per Year

United Kingdom:

The data for the United Kingdom was derived from a table entitled *Carbon Dioxide Emissions in the UK* mounted at the Web Site of the Department of Trade and Industry. This data was prepared by the National Environmental Technology Centre for the National Environmental Atmospheric Emissions Inventory.[8] Data for the year 2000 was preliminary. As in the case of Canada, this information was inadequate to construct the full spreadsheet.

Two values were published for the emissions from the transportation sector. The values calculated by the IPCC definition were chosen over those calculated by the UNECE definition because they were about 10% lower. The lower option is more likely not to include other emissions from stationary sources that may be charged to the transportation sector (from oil refineries, pipelines, etc.) and so should approximate more closely those only from mobile sources. A table was also provided listing carbon dioxide emissions from each of the fossil fuels. The emissions from oil were divided into the emissions from the transportation sector to calculate C_{T1}. As was the case for Canada, this introduced a small error as some natural gas was included in the transportation total. Similarly, the emissions from the total of all the fossil fuels was divided into those from the transportation sector to calculate C_{T2}. The slowly declining total carbon dioxide emissions were also included in this graph.

The average value for C_{T1} was 0.602 with a Standard Deviation of 0.039. The average value for C_{T2} was 0.222 with a Standard Deviation of 0.011. C_{T1} rose appreciably throughout this period and there was a small tendency for C_{T2} to increase as well. Unlike the U.S. and Canada, total emissions fell slowly.

Summary:

Two coefficients have been calculated for emissions from the transportation sector as would have been derived from a simple 3x3 spreadsheet that relates carbon inputs from the three fossil fuels - oil, natural gas, and coal - to emissions of carbon dioxide from three consumption sectors - electrical generation, mobile sources and all other stationary sources. The data from the U.S. was sufficient to construct the spreadsheet completely but this was not the case for Canada and the U.K. where some further assumptions were required to derive the two transportation coefficients. The error introduced is not large.

Mean Transport Emission Coefficients for the U.S., Canada, and the U.K. 1990-2000

	C_{T1}	Std. Dev.	C_{T2}	Std. Dev.
U.S.	0.729	0.013	0.317	0.004
Canada	0.645	0.015	0.305	0.005
U.K.	0.602	0.039	0.222	0.011

The results reported in the above table indicate the U.S. dedicates more of its oil consumption to the transportation sector than Canada and the U.K. in that order. In all three countries, the Standard Deviation for C_{T2} is markedly lower than for C_{T1}. In the U.S. and Canada, with rising emissions of carbon dioxide from the fossil fuels, the value of C_{T1} is reasonably constant though the values for C_{T1} are more erratic in Canada. C_{T2} is close to constant in all three countries. The values of the two ratios were lower in Canada and the U.K. than in the U.S. suggesting more oil could be devoted to the transportation sector in the former two countries without great strain.

In the case of the U.K., the value of C_{T1} rose continuously through the period. Given that total carbon dioxide emissions from the fossil fuels fell slowly over these years, these results suggest there was a structural change underway in the U.K. energy economy. This was perhaps due to the steady substitution of natural gas for coal and the non-transportation applications of oil.

The main advantage of using the spreadsheet method is that the data used must be self-consistent. Given that the coefficients change only slowly over time, they may be used in conjunction with projections of energy demand to prepare estimates of the situation at some future time. Should such projections require unreasonably fast changes in these coefficients, the predictions should be regarded with caution. Too fast changes in these values, as may have been the case in the U.K. over this period, would indicate that the energy economy has entered a period of stress.

References

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6. *Canada's Greenhouse Gas Inventory 1990-2000*, Environment Canada, June 2002. (Web: www.ec.gc.ca/pdb/ghg/ghg_docs/2000nir-e.pdf)

7. J.H. Walsh, *Carbon Dioxide Factsheet.* Prepared from data published in the *B.P. Statistical Review of World Energy* each year. (Web: pages.ca.inter.net/~jhwalsh/fsesr.html)

8. *Carbon DioxideEmissions in the U.K.* Data from the National Environmental Atmospheric Emissions Inventory mounted at the Web Site of the Department of Trade and Industry at www.dti.gov.uk.

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