Eurostat's regular estimations of CO2 emissions from final use of products in the EU

Stephan Moll, Eurostat

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Abstract

This paper provides an estimate of carbon dioxide (CO2) emissions induced by the final use of products, based on various European Union (EU) data sets. Eurostat estimates the EU-27's CO2 emissions from final use to have been 8.0 tonnes per inhabitant during 2009 (the year when the financial and economic crisis was at its height).

The modelling-estimations presented in this article are based on environmentally extended input-output tables. Eurostat produces and publishes on a regular basis Air Emissions Accounts (AEA) and monetary Supply and Use, and Input-Output Tables (SUIOT). Both are connected and used for Leontief type IO modelling to estimate 'carbon footprints' associated to final use of products in the EU economy.

The data provides an opportunity for analyses by researchers and policy advisors — some illustrative examples of the use that may be made of this information are also presented.

Introduction

Over recent years the issues of 'carbon footprints' and 'carbon leakages' have been gaining attention in the climate change policy debates.

In a national accounts context 'carbon footprints' denote the direct and indirect emissions of carbon dioxide (CO2) attributable to the final use of products in a national economy. They include all CO2-emissions arising along the production chains of the products finally used by the respective country. The indirect component includes conceptually the CO2-emissions which arise outside the country and which are associated with the imports of goods and services. The 'carbon footprint' of a country may deviate from the actual CO2-emissions occurring on the territory of the respective country.

Carbon leakage occurs when there is an increase in carbon dioxide emissions in one country as a result of an emissions reduction by a second country.

The political discussions of these issues are often of an anecdotal nature due to the lack of quantitative evidence. It is impossible to actually measure 'carbon footprints' and the robustness of the various estimation methods is still subject of scientific explorations and evaluations.

Environmentally extended input-output analysis is one method to estimate 'carbon footprints' in a nationals accounts sense. It is based on official statistics and a standardised method, i.e. the results

are transparent and reproducible. However, this method also depends on certain model assumptions which need to be communicated transparently when presenting the results.

Data and method

Consolidated supply, use, and input-output tables (product-by-product) at basic prices for the EU-27 and euro area:

Under the European System of National and Regional Accounts (ESA), EU Member States transmit to Eurostat Supply and Use Tables (SUT, annually) and Input-Output Tables (IOT, 5 yearly). The compilation of SUTs is very time and resource consuming; they are submitted only 36 months after the end of the reference period. A Supply table shows the supply of goods and services by product and type of supplier at basic prices, while the Use table shows the use of goods and services by product and type of use at purchaser prices. These tables transmitted by Member States formed the point of departure for a sequence of manipulations leading to a consolidated data set for the aggregated EU27 and the euro area.

For each Member State, SUTs at basic prices were estimated with the available SUTs (in basic/purchaser prices) and (in part confidential) auxiliary valuation data. Due to confidentiality reasons the SUTs are published only for the aggregated EU27 and euro area.

The SUTs for the individual Member States are aggregated to EU27 and euro area SUTs. The main sub-steps include:

- For each Member State, the *Use* table is subdivided into an *Import Use* and *Domestic Use* part, and subsequently in an *Intra-EU Import Use* table and an *Extra-EU Import Use* table.
- Each of the *domestic use*, *intra-EU import use*, and *extra EU import use* tables are aggregated across countries to EU27 totals.
- A confrontation and rebalancing takes place of the *intra-EU import use* total with the *intra EU export supply* totals – which in theory should be identical apart from valuation differences, but in practice are not so, due to the fact that the data are collected and reported independently by different countries and hence may be subject to statistical differences.
- The relatively small intra EU export/import differences are moved to the rest of world. The *intra-EU import use* and *intra-EU export supply* data are now identical and cancelled each other out. The aggregated EU27 SUT now can be created by aggregating the individual country *Domestic SUTs* and *extra-EU import Use* and *export Supply tables*.
- The aggregated SUTs are transformed into symmetric product-by-product *Input-Output Tables* (IOTs). A product by product IOT shows which products form input into the production of another product, and conversely, for what purposes this product is used. A

transformation matrix is calculated according to market shares. This market share matrix shows the relative amount of product output by each industry. The transformation matrix is then multiplied by the use matrix to give the symmetric Input-Output table (product-by-product). In the transformation matrix used here, the so-called industry technology assumption is applied (see Model B, Eurostat (2008) Manual of Supply, Use and Input-Output Tables, p.349).

The resulting data set comprises in total six tables, each for the aggregated EU27 and the euro area. Two time periods are covered:

- 2000 to 2007 (NACE rev.1.1)
- since 2008 (NACE rev.2)

Further information on the ESA Supply, Use, and Input-Output Tables can be found here: (http://epp.eurostat.ec.europa.eu/portal/page/portal/esa95_supply_use_input_tables/data/workbooks).

Air Emissions Accounts by activity (NACE industries and households)

Eurostat's Environmental Accounts programme publishes regularly Air Emissions Accounts recording emissions of greenhouse gases and air pollutants in the same format as used for SUT and IOT (i.e. in a breakdown by industries and households).

Data for eight pollutants (CO2, N2O, CH4, SOx, NOx, NH3, CO, NMVOC) were added to the above mentioned consolidated SUTs and IOTs for the aggregated EU27 and euro area.

Further information on Eurostat's Air Emissions Accounts can be found here: (http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/introduction).

The Leontief-type model

Calculation of the Leontief model and extending it by environmental (or other) parameters is a standard operation in input-output analysis (e.g. Miller and Blair, 2009).

In a first step, an input-coefficient matrix $\boldsymbol{A}$ is calculated which shows for each homogenous production branch how much direct inputs (of other products) are needed to produce one unit of its typical product output.

In a second step, the Leontief matrix $\boldsymbol{L}$ is derived. The Leontief inverse shows how much direct and indirect requirements (inputs of other products) are needed in order to produce one unit of a product for final use.

In a third step, environmental extensions are added – i.e. the vector of CO-emissions by industries $\boldsymbol{z}$. Environmental input-coefficients $\boldsymbol{zA}$ are calculated which express how much CO2 per unit output is

emitted by a respective industry. The environmental input coefficient vector is diagonalised *diag(***z***A)* and multiplied with the Leontief matrix. The resulting is termed multipliers $\boldsymbol{M}$; showing how much of a given environmental parameter is directly and indirectly required to produce one unit of a product for final use.. Multipliers are then multiplied by each category of final use to give the domestic or total upstream requirements for each product in each category of final use $\boldsymbol{E}$. Direct emissions for households $\boldsymbol{H}$ are allocated in addition to the household final demand category. The mathematical formulations are given in Box 1.

Two variants of environmentally extended Leontief models have been established in this project. The first one re-attributes only the territorial CO2-emissions arising from domestic production activities to the final use. The second model estimates in addition 'carbon footprints' of imports.

Version 1 (only domestic intermediates)

In version A, the input coefficient matrix $\boldsymbol{A_d}$ and subsequently the Leontief inverse $\boldsymbol{L_d}$ are calculated from the domestic component of the symmetric input-output table such that only domestic transactions are included in the direct and indirect requirements. Total requirements, or multipliers, are presented by product group. This representation maintains data integrity of the multipliers (based only on statistical data) without the need for making assumptions on technology in trading partners, but necessarily ignores the import of products. The environmental repercussions of importing products rather than producing them domestically are hence ignored.

Version 2 (domestic and import intermediates)

In Version B, the coefficients matrix $\boldsymbol{A}$ and subsequently the Leontief $\boldsymbol{L}$ inverse are calculated from the total (domestic + import) components of the symmetric input-output table such that both domestic and imported transactions are included in the direct and indirect requirements. This representation assumes that trading partners have the same technology of production as domestically, and is commonly known as the 'domestic technology assumption' (DTA. The environmental repercussions of importing products are then captured, with the assumption that the same impact would occur in foreign locations per Euro of production as that which occurs locally.

The DTA implies that actually avoided CO2-emissions are calculated, i.e. the amount of CO2 which would have been emitted if domestic industries would have produced the imported goods and services. In other words the 'avoided' CO2-emissions are used to estimate/approximate the 'carbon footprints'.

Further information can be found in a technical documentation:
http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/documents/eeSUIOT%20TechDoc%20final%20060411.pdf

Box 1: Mathematical formulation

Input coefficient matrices are derived by dividing the columns of the intermediate ***S*** by the total domestic output of products ***q***.

$A = S(\text{diag}(q))^{-1} = U(\text{diag}(g))^{-1} V(\text{diag}(q))^{-1}$

$A_d = S_d(\text{diag}(q))^{-1} = U_d(\text{diag}(g))^{-1} V(\text{diag}(q))^{-1}$

where A_d is derived from the "domestic only" case (version A).

Leontief inverses are calculated from the above input coefficient matrices

$L = (I-A)^{-1}$

$L_d = (I-A_d)^{-1}$

Physical input coefficients are derived for the environmental extensions:

$Z^A = Z(\text{diag}(q))^{-1} = R(\text{diag}(g))^{-1} V(\text{diag}(q))^{-1}$

Environmental multipliers are calculated according to:

$M = Z^A L$

$M_d = Z^A L_d$

Emissions embodied in final demand are calculated according to:

$E = M \cdot Y + H$

$E_d = M_d \cdot Y + H$

$E_m = E - E_d$

Results

The model estimations described above reveal that the CO2 emissions attributable to the EU-27's final use of products amount to 8.0 tonnes per inhabitant during 2009 (the year when the financial and economic crisis was at its height).

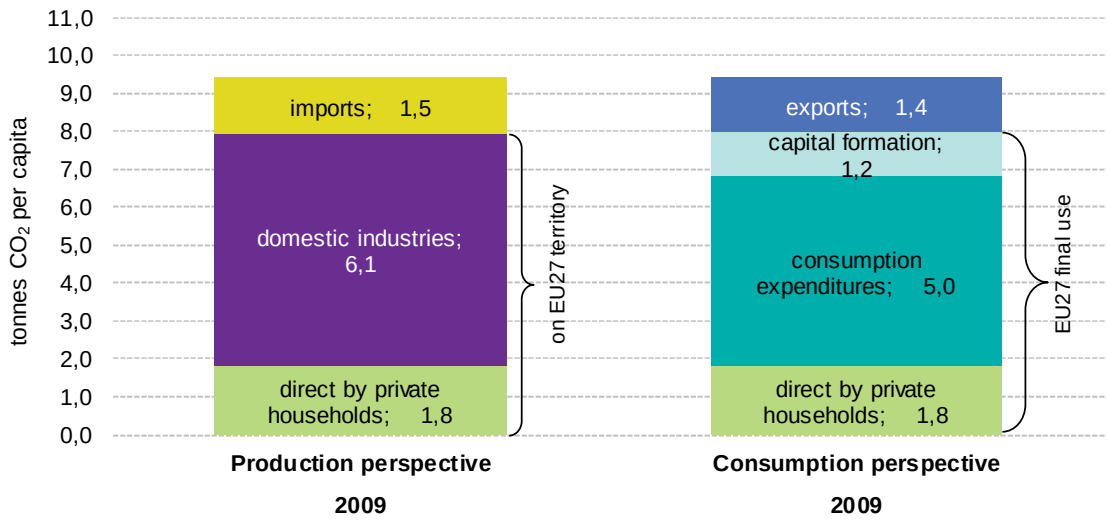
The EU-27 total of 8.0 tonnes of carbon dioxide emissions per inhabitant in 2009 was composed of three main elements (see the right-hand bar of Figure 1 'consumption perspective'):

- some 5.0 tonnes per inhabitant resulted from the consumption by households and governments of goods and services;
- a further 1.8 tonnes per inhabitant resulted from direct carbon dioxide emissions from private households in the EU-27 (for example, through the burning of fossil fuels for private vehicles or for heating);
- another 1.2 tonnes per inhabitant resulted from (production related to) investments — also referred to as gross capital formation — in the EU-27 economy.

Figure 1 also shows the 'carbon footprints' of exports (right-hand bar 'consumption perspective'). They are estimated to 1.4 tonnes CO2 per inhabitant. They are only slightly lower than the estimated 'carbon footprint' of the imports into the EU economy (1.5 tonnes CO2 per inhabitant, see left bar of Figure 1 'production perspective').

The left-hand bar of Figure 1 ('production perspective') further presents the CO2 emissions attributable to the domestic production activities of EU industries (6.1 tonnes CO2 per inhabitant). In addition the direct emissions of households (1.8 tonnes CO2 per inhabitant) need to be considered from a 'production perspective'.

Figure 1: Domestic and global CO2-emissions induced by EU27 - production and consumption perspective, 2009, in tonnes CO2 per inhabitant



Source: Eurostat (online data codes: env_ac_ainah_r2, and env_ac_io_r2)

Figure 2 shows the development over time. The upper line presents the model estimates of the domestic and global CO2-emissions associated with the domestic final use of products in the EU-27 economy ('carbon footprints'). It clearly shows that the crisis year 2009 came along with a significant drop by 1.5 tonnes per capita. Between 2000 and 2007 the 'carbon footprints' of EU-27 final use of products have been on higher level fluctuating around 9 tonnes CO2 per capita.

Figure 2 also compares the Eurostat model estimates with the CO2-emissions reported in greenhouse gas (GHG) inventories. By and large they have been developing in a very close pattern. However, they are structurally lower than the estimated 'carbon footprints' mainly due to the fact that emissions from international transport activities are excluded.

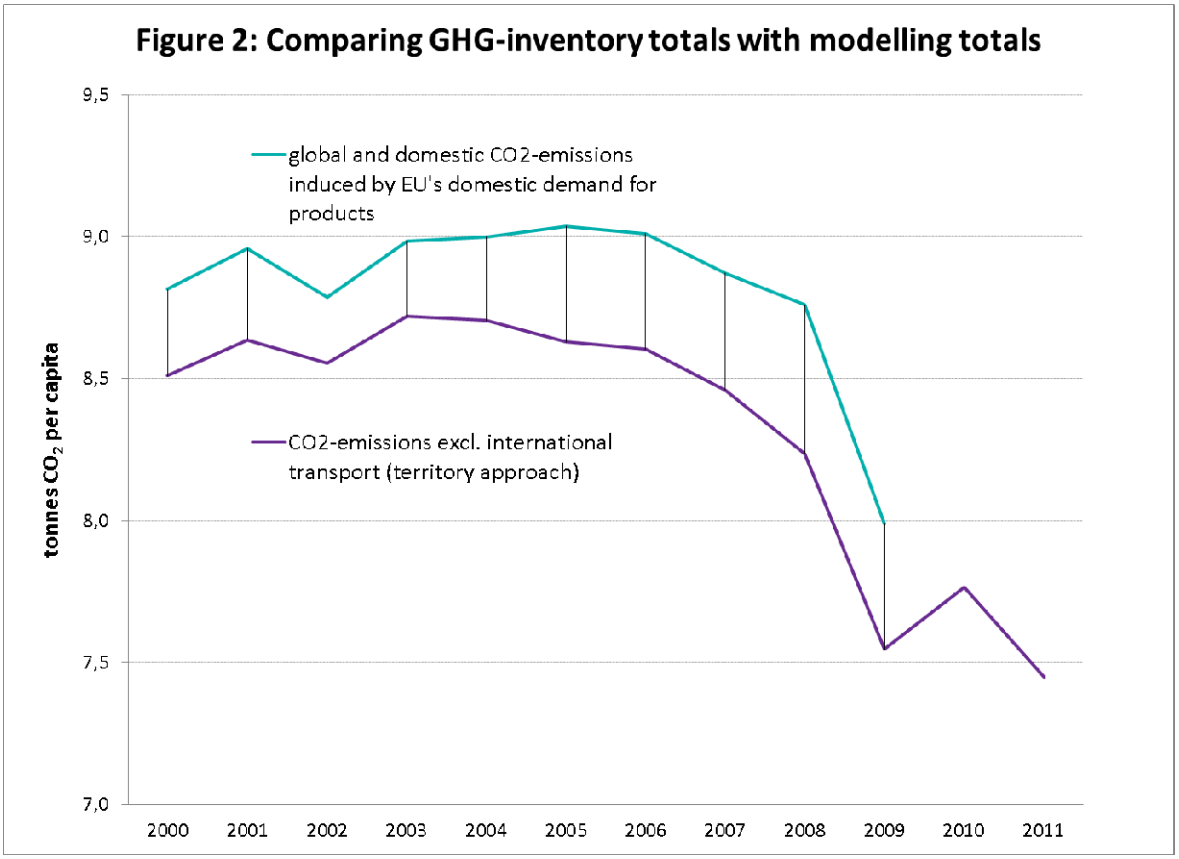


Table 1 provides a more detailed breakdown of the carbon dioxide emissions that were induced in 2009 by domestic final use of products ('carbon footprints'), according to a range of different product groups and categories of final use. These are ranked according to their importance in the terms of their respective share of emissions: electricity, gas, steam and air-conditioning; constructions and construction works; food products, beverages and tobacco products; and; public administration, defence and compulsory social security services ranked as the four product groups with the highest levels of emissions per inhabitant in 2009 as a result of their final use.

References

Eurostat (2008): Manual of Supply, Use and Input-Output Tables. Luxembourg: Office for Official Publications of the European Communities.

Miller, R.E., Blair, P.D. (2009): Input-output analysis: Foundations and extensions. Cambridge, UK: Cambridge University Press.

Table 1

Global and domestic CO2-emissions induced by final use of products, EU-27 2009, kg per capita

CPA product group	Final consump-tion	Gross capital formation	Exports	Final use, total	
	(kg of CO2 per inhabitant)				(%)
Electricity, gas, steam and air-conditioning	1.032	16	48	1.097	11,7%
Constructions and construction w orks	38	672	3	713	7,6%
Food products, beverages and tobacco products	432	2	47	481	5,1%
Public administration and defence services; compulsory social security services	301	1	1	303	3,2%
Coke and refined petroleum products	196	-4	80	272	2,9%
Motor vehicles, trailers and semi-trailers	139	45	67	251	2,7%
Chemicals and chemical products	97	-4	157	250	2,7%
Retail trade services, except of motor vehicles and motorcycles	217	14	16	247	2,6%
Wholesale trade services, except of motor vehicles and motorcycles	156	37	49	241	2,6%
Accommodation and food services	223	1	4	228	2,4%
Land transport services and transport services via pipelines	199	8	18	225	2,4%
Human health services	219	0	0	219	2,3%
Machinery and equipment n.e.c.	6	101	110	217	2,3%
Air transport services	139	-2	65	202	2,1%
Water transport services	39	1	148	188	2,0%
Education services	144	0	0	145	1,5%
Textiles, w earing apparel and leather products	117	-3	25	139	1,5%
Products of agriculture, hunting and related services	110	8	13	132	1,4%
Other products	1.196	273	569	2.038	21,7%
Total	**5.002**	**1.166**	**1.421**	**7.589**	**80,6%**
Direct emissions by private households	1.821	0	0	1.821	19,4%
All CPA products plus direct emissions by private households	**6.823**	**1.166**	**1.421**	**9.410**	**100%**

Source: Eurostat (online data codes: env_ac_io_r2); CPA = Statistical classification of products by activity